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Carl G. Bailey
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EXAMINING THE EFFECTIVENESS OF COMPUTER ANIMATIONS
AS A TOOL IN TEACHING
HIGH SCHOOL INTRODUCTORY CHEMISTRY

by

Carl G. Bailey

A Research Project Presented in Partial Fulfillment
of the requirements for the Degree
Master of Education

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Has been approved

October, 2006

APPROVED:

______________________________, Faculty Advisor

______________________________, Associate Dean, Teacher Education Programs

ABSTRACT

Examining the Effectiveness of Computer Animations as a Tool in Teaching High School Introductory Chemistry

Computer animations may provide educators with a viable way to address chemistry's abstract nature. Current research suggests that students benefit from even short exposure to computer animations of molecular events. This applied study examined the potential benefit of using computer animations to enhance traditional teaching techniques. Two groups of students, one taught with computer animations and one taught without computer animations, completed the same assessments. Statistical analysis of the assessments provides evidence that the use of computer animations leads to improved student comprehension of microscopic processes and their relationship to macroscopic phenomena occurring in gases.

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Chapter 1

INTRODUCTION

Thorough comprehension of chemistry at the atomic and molecular level requires the ability to visualize the interaction of atoms and molecules. Historically, mathematical analysis has been used to generate graphs and charts that served as visual images of these processes. Since atoms and molecules cannot be seen with an imaging technology, the ability to mentally visualize atomic and molecular processes may determine a student's degree of comprehension of the processes under study. Computer animations of atomic and molecular interaction have become readily accessible with the emergence of computer technology and the internet. Using computer-generated animations of atomic and molecular interactions may help students to visualize these interactions and further their understanding of various concepts. The hypothesis of this study is that students having the opportunity to visualize gases at the atomic and molecular level through computer animations will demonstrate an increased ability to answer subjective and objective questions requiring comprehension of the behavior of gas particles and the resulting emergent properties of gases.

The field of chemistry is abstract in nature. Interactions at the atomic or molecular level, which I will refer to as the microscopic level from this point on, cannot be seen. As a result, students often fail to fully comprehend many of the concepts that they study. Specifically events occurring at the microscopic level, and how those events relate to larger observable macroscopic phenomena have traditionally been difficult for students to learn. This applied project addressed the difficulty students have with applying the rules of kinetic theory of gases to the behavior of a real gas sample. The purpose of this study was to establish whether or not using computer animations would increase students' learning and comprehension of microscopic events occurring in gasses, and whether or not using computer animations would help students to develop the ability to comprehend how these microscopic events are related to macroscopic events.

Given chemistry's abstract nature, particularly the illusive microscopic level, an important question for educators is raised: How has chemistry been taught in the past, and is there really a need to incorporate animations into any chemistry curriculum? Chapter Two discusses how chemistry has traditionally been taught and explore why chemistry has traditionally been a difficult topic for most students. Typically, chemistry is taught with a focus on three main components: *macrochemistry*, the tangible or visible; *microchemistry*, the molecular and atomic level as well as kinetics, and the *representational* level which consists of symbols, chemical equations, stoichiometric ratios and mathematical analysis (Johnstone, 1993). The ability to move conceptually between these three levels and thus recognize the relationship between these levels is very rare for the average high school chemistry student. Some high school students may not even recognize that a relationship exists between these three levels. The typical high school chemistry student will experience some success in understanding the macroscopic and representational levels, but struggles the most with the microscopic level; he level that cannot be seen. Without the benefit of having somewhat of a grasp on *all* three levels, the overall ability of a student to comprehend chemistry is compromised. The use of computer animations in teaching chemistry is relevant in that computer animations may serve to strengthen the students' ability to comprehend the microscopic level thereby improving their overall understanding of chemistry.

Chapter Three discusses how this study was configured. Briefly, the control group was taught using traditional lecture supplemented by demonstrations and laboratory experiments. The experimental group was taught using traditional lecture, demonstrations, laboratory experiments, and computer animations. The same assessments were administered to both groups. Questions targeting students' comprehension of how microscopic events relate to macroscopic phenomena in gases were included. Responses to these assessment questions were compiled and are summarized in Chapter Four. Analyses of students' responses are carried out in Chapter Five to assess the effectiveness of computer animations as a teaching tool thereby proving or disproving the hypothesis.

Summary

Effective comprehension of chemistry requires understanding three essential levels or components of chemistry: macroscopic, representational and microscopic. The unseen microscopic level is what makes chemistry abstract for many high school students. Without an understanding of the microscopic processes, and therefore all three levels, students' comprehension of basic concepts in chemistry is incomplete. The author is proposing the use of computer animations as a means to improve students' ability to comprehend microscopic events and the relationship between microscopic and macroscopic phenomena occurring in gases.

*Definition of Terms**

Absolute temperature scale:	A temperature measurement made relative to absolute zero – the lowest possible temperature, all molecular motion ceases.
Avogadro's Principle:	Equal volumes of different gases under the same temperatures and pressures will have the same number of particles.
Bernoulli's Principle:	The pressure a gas exerts decreases if the speed of the fluid increases and vice versa (Buffa, 2000).
Boyle's Law:	The volume of a gas sample at constant temperature is inversely proportional to the pressure.
Charles' Law:	The volume of a gas sample at constant pressure is directly proportional to the absolute temperature.
Dalton's Law of partial pressure:	The total pressure of a gas mixture is the sum of the partial pressures of the individual components.
Effusion:	The motion of a gas through an opening into an evacuated chamber.
Graham's Law:	The rates of effusion for two gases are inversely proportional to the square roots of their molar masses at the same temperature and pressure.
Ideal gas:	A model that effectively describes the behavior of real gases at conditions close to standard temperature (273 Kelvin) and pressure (1 atmosphere).
Kinetic Energy (KE):	The energy that moving objects possess by virtue of their motion. KE=1/2mv2
Pressure:	A function of the number of collisions per unit time on any given object by gas particles.

*All definitions unless cited otherwise were taken from Tocci & Viehland (1996).

Chapter 2

REVIEW OF LITERATURE

Historical Difficulties of Understanding Chemistry

Chemistry, at the high school level, is typically difficult for students to learn because of the abstract nature of the concepts or processes being examined (Johnstone, 1993; Kozma, 1997; Wilensky, 1999 & Wu, 2001). Atoms, molecules and processes happening at the atomic level cannot readily be seen. As a result, the average chemistry student experiences difficulty in visualizing the atom, interactions between atoms and atomic processes. Quantitative data can be collected while observing pressure changes of a gas sample or temperature may be monitored to follow changes in enthalpy of a chemical system. Both of these examples illustrate observations that are the result of processes happening at the atomic or molecular level. The data collected can then be graphed to provide a visual representation of the changes taking place at the molecular level. It is through the interpretation of graphs that patterns and trends throughout various processes begin to emerge, or can "be seen". Consequently, graphs have been relied upon heavily to provide a visual representation of various processes and concepts. As a result, successful chemistry students have been those that are able to grasp abstract concepts and have a strong working background in mathematics. Pence (1993) cites a typical complaint of chemistry students that chemistry courses are typically applied math courses. He goes on to state that the number of successful chemistry students, particularly at the high school level, is potentially diminished as a result of the abstract nature of chemistry and the dependence upon math to generate representational images of the processes being studied.

Traditional Approach to Teaching Chemistry

The traditional approach used to teach chemistry involves three levels of description: *microscopic*, *macroscopic*, and *representational* (Johnstone, 1993). The *macroscopic*, defined as tangible or visible, is touched on through demonstrations and laboratory experiments. For example, students might see a solution change color or that a reaction gives off heat. The next level, *representational*, includes element symbols used in chemical reactions and graphs that represent the changes occurring at the atomic and molecular levels. Although the *microscopic* level, defined as atomic and molecular interaction, is equally important, there has been no way to convey what is happening at this level other than to interpret the representational graphs and mathematic analysis in the context of observable macroscopic events. Typically, the successful chemistry student is one that can generate a mental image of the molecular or atomic processes taking place in accordance with a graph or set of values generated through analysis (Kozma, 1997 & Wu, 2001). This is a tall order for an average high school student. Statistical mechanics, the study of "... the behavior of large numbers of molecules each following individual rules of motion" is a common example of an attempt to comprehend complex behavior that arises from a reasonably simple set of rules (Wilensky, 1999, p. 3).

For example, the pressure a gas sample exerts is a force that emerges from the interaction of numerous particles moving independently. Statistical mechanics are essential to understanding how macroscopic events like pressure emerge out of the microscopic level behavior of atomic particles.

However, Wilensky (1999) cites form a variety of resources that statistical mechanics is one of the most difficult concepts for students at various levels to understand. Konald (1991), Phillips (1998), Piaget (1951), Tversky & Kahneman (1947), and Wilensky (1997) are all cited in Wilensky (1999) documenting the difficulty most people have with statistical and probablistic thinking.

The typical high school curriculum separates the study of micro-level phenomena from macro-level phenomena. The connection between the two is over-looked because of the common struggle students have with statistical thinking. However, the connection between the two may be central to the study of a concept (Wilensky, 1999). For example, the macroscopic-level gas laws, which all chemistry students learn, emerge from models of molecular interactions based on kinetic theory. Previously, this connection would have been demonstrated through difficult mathematical analysis. Now animations can provide an environment that allows these connections between microscopic and macroscopic-levels to be seen without the rigorous mathematical analysis that has traditionally been relied upon.

Connecting the Microscopic and Macroscopic-levels With Animations

Educators have experimented with various approaches to teaching chemistry to make the field more accessible to a greater population of students. Stieff (2005) states that due to chemistry's abstract nature and many unobservable processes and concepts, the learning and teaching of chemistry has traditionally been based upon the use of visual representations to symbolize these events. Pence (1993), Wu (2001) and Kozma (1997) all state that using more visual imagery in class will help to improve the student's observational ability and proficiency at visualizing chemical principles. These authors argue visualizing the unseen processes helps to make the field of chemistry more accessible to the average learner.

Hays (1996) claims computers animations possess some unique qualities that allow it to show concretely the visualizations required in order to form accurate conceptual representations. The unique benefit of using visuals, which include animations, in teaching is supported through Paivio's dual-coding theory (Hays, 1996 & Reiber, 1991) and schematheory (ChanLin,1988). The theory of Dual-coding suggests that information is coded and stored in long-term memory in two different ways, a verbal code and a visual code. The two different codes are additive and reinforce one another. If information is coded both verbally and visually, the information is twice as likely to be remembered (Rieber, 1996). Of greater significance however, is that all information presented to a pupil is not necessarily coded both visually and verbally. Verbal information tends to be coded verbally *only*, whereas visual information is more likely to be coded dually; both verbally and visually. Hence, teaching with visuals results in greater retention of material (Reiber, 1991). The way information is coded is not the only factor that appears to impact learning. How information is stored is also a factor.

Schemata is a term that refers to how knowledge is stored or represented in memory. Schemata are knowledge structures containing procedural components and statements thought to be true by the learner. New information is stored in pre-existing schemata, and a schemata allows a student to make inferences and fill in the gaps in verbal information. It is important for a student to be able to accurately evaluate and modify his or her schemata because a student's schemata of a concept or process may not be correct (Benner, 1988). Therefore, learning is dependent upon a student's ability to form accurate schematic representations.

The power of an animation lays in its ability to provide an accurate interpretation of an event or process, and thus facilitate a student's formation a n accurate schemata (ChanLin, 1998). ChanLin summarizes the effectiveness of animations as a learning tool by stating, "Animation is effective in providing an interpretation model and compensating for knowledge deficiency [lack of background knowledge]. The use of motion also creates another form of coding to facilitate the learning of concepts" (p. 168). Hays (1996) comments, that when learning requires the visualization of a dynamic process or an understanding of how motion relates to a concept, animations do seem to help the learner grasp a concept.

Currently, much enthusiasm has been generated for the use of computer video technology, computer analysis, computer animation and computer assisted molecular modeling to make chemistry a more comprehensible field of study for a broader range of students. Although a relatively old technology, Pence (1993) cites the use of spreadsheets and graphical analysis as a relatively easy yet effective way to build simple visual representations of chemical concepts. This type of software lends itself to inquiry based learning in that students can quickly compare their predictions of how given processes may change to the projections provided by a spreadsheet (Pence, 1993). Pence (1993) goes on to describe how the graphical display possible with spreadsheets seems to make even complex concepts more understandable for students.

Computerized videos offer many advantages as well. The ability to safely show dangerous reactions, or reactions to students that may not be able to see in a large lecture format is very helpful. The ability to replay these reactions as many times as necessary is beneficial also (Pence, 1993). Highly toxic or radioactive chemicals, that illustrate particular concepts well, can be used in any simulation without concern of exposing students to dangerous situations. A simulated nuclear fission reaction is an excellent example.

Computer animation is being used currently to successfully target a long standing problem: "the difficulty students have in connecting macroscopic chemical events with hypothesized changes taking place at the atomic level and the symbolic representations (formulas, equations, etc.) used to describe those events" (Herron, 1999, p. 1358).

Williamson and Abraham, as cited in Herron (1999), have shown that even relatively short exposure to computer animations of molecular events can improve understanding of how the "particles" of matter, atoms and molecules, behave.

Montgomery (2001) has integrated computerized molecular modeling into four common laboratories done by first year college students. He documented how students improved their ability to visualize three-dimensional structures, determine and examine molecular orbitals, compare stabilities of isomers and conformers, determine possible transition states, and calculate spectroscopic properties through the use of computerized molecular modeling. Numerous software packages are available to educators. Coleman and Fedosky (2005) reviewed the use of JCE Webware's web based learning aids. They found that these tools were valuable in helping students to better visualize molecular geometries. JCE's products include self contained lessons, or learning objects, as well as images, videos and animations, referred to as digital assets, that can be assembled in any way an instructor chooses to reinforce any given lesson or unit. Feller, Dallinger and McKinney (2004) describe their software as having the capacity to instruct and engage students in the computations that support the concepts being taught in general chemistry courses. In other words, animations and visual imagery have become vehicles by which students are better able to comprehend mathematical analysis.

Software packages may employ the use of animations and simulations. Both can be effective, however there is a distinction between the two. Computer animations are simply moving images or diagrams (en.wikipedia.org/wiki/ Computer_animation, nd).

Computer simulations are software programs that attempt to simulate any given phenomenon based on a scientist's mathematical and conceptual understanding of the particular phenomenon (fightaidsathome.scripps.edu/glossary.html, nd). Theoretically, any phenomena that can be simplified to data and mathematical equations can be simulated on a computer. Examples include weather conditions, chemical reactions, biological processes or economic forecasts (webopedia.com/TERMS/simulation.html, nd). Students can interact with a simulation by changing variables, predicting the changes that will occur, and then observing the changes that actually take place. The advantage to using animations is that they can diminish the dependency on complex math skills in order to generate visual representations of the processes or concepts being examined. The computer can quickly carry out the calculations and generate images that students can then observe. Through the use of interactive animation software, students can engage in inquiry based learning much more readily, as they can make predictions and then examine immediately how changes in a chemical system will impact various processes. Studying concepts becomes very dynamic. The result of changing variables is immediately apparent.

The obvious drawback to moving instruction toward technology is the cost of the equipment. However, much of the software required is available over the internet, or site licenses can be purchased for a reasonable fee and the software can be used on networked computers. The computers required to run the software are common on college campuses today. Herron (1999) emphasizes the importance of managing any student used software system properly. The author states the emphasis should be to minimize the students' efforts to learn the software so they can concentrate on learning chemistry.

Summary

The enthusiasm that technology is receiving as a viable way to make the microscopic interactions and processes of matter visual appears to be well deserved. Computer animations can empower students by helping them to make the connection between micro-level and macro-level events apparent despite their difficulties with statistical thinking (Wilensky, 1999). Student performance does appear to be improved as a result of computer technology's potential to enhance students' abilities to visualize chemical processes. Feller, Dallinger and McKinney (2004) cites an unforeseen benefit of moving instruction and delivery of chemistry concepts toward technology. The benefit has been an increase in the number of students interested in the field of chemistry.

Chapter Three describes how content covering properties of gases and gas laws was delivered to a control and test population of students. Students in the test group were taught using computer animations in addition to traditional teaching strategies. The same assessments were administered to all students to establish the benefit of using computer animations.

Chapter 3

METHOD

Purpose and Rationale

The purpose of this study was to establish whether or not using computer animations would increase students' learning and comprehension of microscopic events occurring in gasses, and whether or not using computer animations help students to develop the ability to comprehend how these microscopic events are related to macroscopic events.

It was hypothesized that the use of animations would increase students' ability to comprehend how microscopic events are related to macroscopic phenomena. Understanding this connection between the invisible microscopic behavior of gas particles and the observable macroscopic behavior of a gas is difficult for students due to the necessity of reasoning by statistical mechanics. In the context of gasses, statistical mechanics involves predicting the macroscopic or observable behavior of a gas sample based on applying the rules of motion that each individual particle must follow (Wilensky, 1999). Students comfortable with statistical mechanics can more readily understand and predict the properties of gases as these properties emerge from the interaction of particles. Unfortunately, most people struggle with the application of statistical mechanics in a variety of fields (Wilensky, 1999).

Through out this study, no cost animations will be used that are readily available over the inter-net and are not necessarily part of a software package. While complete software packages targeting gas laws, properties of gases, and their microscopic interaction may be beneficial, their use is contingent upon a school having the funds to purchase the software and current operating systems. In addition, teachers or technology support staff must be available to trouble shoot and ensure the system runs efficiently, as well as train others in the use of the software package. Herron (1999) warns that if software packages are to be used effectively, technical resources must be in place so the emphasis is on the study of chemistry and not mastering animation software.

The average introductory high school chemistry course curriculum devotes three to four weeks to cover gases and gas laws. High schools willing and or able to make the monetary commitment to purchase software targeting such a small portion of their curriculum will be the minority. In order to encourage the use of the instructional approach developed in this study, the author has deliberately chosen to use no cost computer animation software. The computer animations compiled during this study have been organized by concept. This is simply a suggestion as to how animations can be integrated into a typical high school setting without requiring a large time commitment or extensive experience working with computers in order to implement them in the classroom.

Target Population

Introductory level chemistry students at a suburban high school will serve as the population for this study. It is worth noting that introductory level chemistry at this school is referred to as College Preparatory Chemistry. Students completing this course successfully are well prepared for introductory level college chemistry. Most students enrolling in the course have taken a physical science course their freshmen year and an introductory level biology course as sophomores. Most students enrolled in this level of chemistry have completed their previous course work with C's or better and are currently enrolled in algebra two, algebra two-trigonometry, or pre-calculus-trigonometry. A voluntary poll taken by the author indicates that approximately 95% of these students plan on attending college, however less than 20% are seriously considering majoring in some field of science.

Procedures

Four sections of College Preparatory (CP) Chemistry were randomly divided into 2 groups. Two sections served as Group A and two sections served as Group B. Each group contained approximately 50 students. Group A was taught using traditional lecture supplemented by demonstrations and laboratory experiments. Group B received the same instruction, however the content of lectures, observations and explanations of demonstrations, and the analysis of laboratory experiments were all explained or analyzed through the use of computer animations. In short, the instructor showed students computer animations that allowed students to see how the behavior and interaction of gas particles relates to a specific concept. Computer animations were used as the culminating activity before moving onto another concept. While students viewed the computer animations, the author insured that students were interpreting what they were seeing correctly by asking students to explain the behavior of the particles in the context of kinetic theory. This project is not focused on evaluating specific animations or experimenting with different techniques as to the delivery of computer animations in the classroom. The goal is to simply assess whether or not the opportunity to view the microscopic through animations can improve students' ability to make the connection between microscopic events and macroscopic phenomena thereby improving their conceptual understanding of the properties of gases and gas laws.

The author recognizes the distinct difference between animations and simulations. The specific differences were discussed in Chapter 2. Although some computer animations used by the author have the ability to be used as simulations, it is the computer animation aspect that the author was focusing on. Animations, and their impact on learning, were the focus of this study for reasons outlined in the section entitled "Purpose and Rationale" in Chapter 3. The specific topics and concepts of this gas unit that were supplemented by animations are listed in Table 1 below. All animations are listed in the Group B Column, as the use of animations is the fundamental difference between Group A and Group B.

Table 1

Gas Law Unit Curriculum and Corresponding Computer Animations

Group A - Curriculum	Group B - Computer Animations
Kinetic Theory Gas Model	
• Distance between particles is great compared to their own diameters	http://mutuslab.cs.uwindsor.ca/schurko/animations/phasesofmatter/phasesofmatter.html Compare phases of matter http://mutuslab.cs.uwindsor.ca/schurko/animations/phasescontainers/phasescontainer.html Compare phases of matter http://mutuslab.cs.uwindsor.ca/schurko/animations/waterphases/status_water.htm Examine phases of water as temperature increases
• Particles are in rapid, random motion, and collisions are perfectly elastic	http://mutuslab.cs.uwindsor.ca/schurko/animations/collisions/collision_particle.htm Elastic collisions
• No attractive forces between particles exist	http://mutuslab.cs.uwindsor.ca/schurko/animations/brownian/gas2d.htm Brownian motion
• Average KE of particles is proportional to temperature	http://celiah.usc.edu/collide/1/ Compare the distribution of molecule speed to molecule size http://mutuslab.cs.uwindsor.ca/schurko/animations/idealgas/idealGas.htm Ideal Gas – Change number of particles, pressure and velocity
• Real gases vs. Ideal gases	http://mutuslab.cs.uwindsor.ca/schurko/animations/idealatmosphere/idealatmosphere.html Ideal atmosphere – change number of particles, mass of particles and temp

Table 1 (continued)

Group A - Curriculum	Group B - Computer Animations
Four Variables of Any Gas • Temperature • Pressure • Volume • Number of particles	http://intro.chem.okstate.edu/1314F00/Laboratory/GLP.htm Gas Law Program http://mutuslab.cs.uwindsor.ca/schurko/animations/idealgas2/pvt.htm Graph select variables of a gas

Properties of Gases
• Gases expand to fill their container
  ○ Demo: Bromine tube
 	
• Gases are easily compressed. Liquids & solids are practically non-compressible.
  ○ Demo: Syringe with air vs. water	

• Gases diffuse rapidly ○ Demo: Ammonium hydroxide & concentrated HCl	http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/animations/diffusionV8.html Process of diffusion http://lessons.harveyproject.org/development/general/diffusion/diffnomemb/diffnomemb.html Process of diffusion

• Gases seek maximum entropy
• Gases exert pressure
  ○ Demo: Pop can crushing
  ○ Demo: Balloon in a vacuum	

Bernoulli's Principle	

Table 1 (continued)

Group A - Curriculum	Group B - Computer Animations
Boyle's Law	http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/gasesv6.swf Compare all four variables, two at a time, with narration
	http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/gaslaw/boyles_law_graph.html Boyle's Law
Charles' Law	http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/gaslaw/charles_law.html Charles' Law
Absolute zero	http://www.colorado.edu/UCB/AcademicAffairs/ArtsSciences/physics/PhysicsInitiative/Physics2000/bec/temperature.html Tutorial and visualization of absolute zero, also links to an array of chemistry concepts.
Avogadro's Principle	http://mutuslab.cs.uwindsor.ca/schurko/animations/avogadro/avogadro.htm Avogadro's Principle - Molecular Weight, Pressure and Average Molecular Speeds
Effusion	http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/animations/Effusion2.html Compare rate to particle size
	http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/gaslaw/effusion_macro.html Compare rate to particle size and generate data
Gay-Lussac's Principle	
Graham's Law	

Goals

The goal behind implementing computer animations into the curriculum covering properties of gases and gas laws was to improve students' overall conceptual understanding of why gases behave the way they do. Specifically, the hope was that students would be able to better visualize how specific variables like temperature, pressure, volume, and number of gas particles, influence a sample of gas. As discussed in Chapter 5, by helping students to see the connection between microscopic events and macroscopic phenomena, this goal should was achieved. The method of analysis of student performance on assessments will be discussed in the section entitled "Assessment".

Using a gas law formula can be very effective in predicting how the pressure and volume of a fixed number of gas particles at constant temperature may change. Specifically, Boyle's law (initial pressure x initial volume = final pressure x final volume) can be used as long as the student can identify three of the four variables identified in the formula. However, the author has observed that numerous students capable of manipulating gas laws like Boyle's law may not be able to answer conceptual questions. Conceptual questions might describe a particular gas undergoing specific qualitative changes, and ask the student to predict how the changes will influence the sample of gas. Without mention of specific values in the question, and therefore the inability to use a mathematical formula, the author has witnessed that many students struggle. The fact that this gap between mathematic and conceptual understanding of the gas laws exists is evidence that a mathematically competent student has failed to grasp the conceptual nature of the properties of gases and gas laws. It was conceptual understanding that the author had hoped to improve through the use of computer animations.

Assessment

The same assessments were administered to all students. The assessments included a quiz consisting of 32 questions after the properties of gases have been introduced, two small free response quizzes and one large comprehensive exam upon completion of the unit. The quiz consisting of 32 questions and the unit exam included true/false and multiple-choice questions. Each assessment consisted of questions ranging from basic to higher level thinking questions. Free response questions were evaluated using a grading rubric to ensure the uniform evaluation of responses. All students were given the same time to complete a particular assessment. Refer to Appendix A for sample assessments and rubric.

Group A and Group B students all came from of the same population of students, therefore it was assumed that any variances that exist within each group are approximately the same. This assumption is referred to as the assumption of the homogeneity of variances (Ravid, 1994). This assumption that no statistical academic differences exist between the two groups, was tested by performing a two-tailed T-test comparing Group A's and Group B's performance on a previously administered exam and their semester grade measured as a percentage. The two-tailed test is used to test a nondirectional hypothesis, that is, no significant difference exists between these groups' performance on assessments in either direction, higher or lower. The criteria established for acceptance of this hypothesis was a *p* value or alpha level of less than .05. Each assessment administered to students during this gas law unit was analyzed using a one-tailed T-test. One-tailed T-tests are used when a directional hypothesis is stated. For example, the hypothesis of this study stated that students using computer animations will better understand concepts and thus out perform students that did not have the benefit of computer animations. The results of each assessment were considered to be statistically significant if the *p* value or alpha level was less than .05. Finally, a survey was given to Group B students to assess the role of the computer animations from their perspective. Students were able to report how animations helped or hindered their comprehension of various concepts. Refer to Appendix B for a copy of this survey. Student responses are reported in Chapter four.

Summary

The purpose of this project was to utilize no cost computer animations that would provide students with an opportunity to visualize the microscopic events occurring in gases and their relationship to macroscopic events. Approximately 100 chemistry students attending a suburban high school were used for this project. Two groups of students were established. Group A was taught using traditional lecture enhanced by demonstrations and laboratory experiments, while Group B received the same instruction further enhanced through the use of computer animations. The hypothesis proposed, that when students are assessed, the students exposed to computer animations would demonstrate increased comprehension of the relationship between microscopic behavior and macroscopic events occurring in gases. The same subjective and objective assessments were administered to all Group A and B students. Each assessment was analyzed using a one-tailed T-test.

Chapter 4 presents the results of the assessments completed by Group A and Group B. The results were based on one-tailed T-test analysis to determine whether a statistically significant difference in performance existed between Group A and Group B. A *p* value of less than .05 deems the assessment results to be statistically significant. The results of a student completed survey questioning the role of animations is also reported.

Chapter 4

RESULTS

Background

Identical assessments were given to two groups of chemistry students studying the properties of gases and gas laws. Group A was taught using traditional lecture supplemented by demonstrations and laboratory experiments. Group B received the same instruction, however the content of lectures, observations and explanations of demonstrations, and the analysis of laboratory experiments was all explained or analyzed through the use of computer animations. Group A consisted of 48 students, while group B consisted of 50 students. Most of the students in Groups A and B have taken a physical science course their freshmen year and an introductory level biology course their sophomore year, completing these courses with C's or better. Further, students in these groups were enrolled in algebra two, algebra two-trigonometry, or pre-calculus-trigonometry.

The hypothesis of this study was that students having the opportunity to visualize gases at the atomic and molecular level through computer animations would demonstrate an increased ability to answer subjective and objective questions requiring comprehension of the behavior of gas particles and the resulting emergent properties of gases. Due to the directional hypothesis of this study, one-tailed T-tests were used to analyze each assessment that was given to Group A and Group B. Student performance on assessments was considered to be statistically significant if the *p* value was less than .05. The *p* value of .05 indicates that the observed differences in the results of an assessment could be due to chance only 5 % of the time. Semester grades of Group A and Group B, as well as their performance on a previous exam, were also evaluated using a two-tailed T test. This test was used to ensure that academic variances between these two groups were not statistically significant. A *p* value of less than .05 indicates that the assumption of homogeneity of differences must be rejected (Ravis, 1994).

Results of Assessment Analysis

Table 2 lists the *p* values that were derived through the one-tailed T-test analysis for each assessment. The degrees of freedom are 96. Variance among assessment scores is not included as a T-test includes variance as a factor in the statistic.

Table 2

T-test of Gas Unit Assessments: Analysis by *p* value

Assessment	*p*
Property of Gases Quiz	.044*
Selected questions	.001**
Kinetic Theory: Short Answer Quiz	.217
Selected questions	.085
Boyle's & Charles' law: Short answer	.100
Gas Law Exam	.114
Selected questions	.154

Note. $*p < .05$. $**p \leq .001$.

Specific questions on given assessments were also selected and analyzed. These questions were higher order conceptual questions as opposed to questions targeting relatively simple factual information. The results of the analysis of these higher order questions also appear in table 2 under the heading "Selected questions". The first assessment "Property of Gases Quiz" shows a *p* value of .044, while selected questions from this assessment show a *p* value of .001. Selected questions from the second assessment, "Kinetic Theory: Short Answer Quiz", show a *p* value of .085, while all other assessments show a *p* value of .1 or larger.

Table 3 shows the results of the two-tailed T-test used to analyze the variation in academic ability between Group A and Group B. Analysis shows a *p* value of .55 for a previously administered unit exam on stoichiometry, and .41 for the previous semesters grade.

Table 3

Baseline Scores of Group A and Group B Compared by *p* Value

Assessment	*p*
Stoichiometry Exam	.56
Semester Grades by percentage	.42

Survey Results

Table 4 includes the results of a student survey regarding the use of animations in instruction during this gas law unit. Students responded to 8 statements regarding the use of animations during class and the degree to which they found the animations to be helpful while studying concepts through out this unit. Students could assign any given statement a score of 1 through 10, 1 representing strong disagreement, 5 representing agreement, and 10 representing strong agreement. The majority of students agreed with each statement. Agreement ranged from 74% to 96%. The percentage of students committing to a stronger level of agreement, awarding statements a score of 7 or higher, ranged from 43% to 80%.

Although the survey only measured student attitudes about the use of animations, the overwhelming response to the use of computer animations was very positive. Nearly all students indicated that they felt the animations were helpful. Specifically, the consensus was that the animations made the information introduced during lecture easier to understand. Eighty five percent of students agreed to visualizing the computer animations they saw when attempting to understand and explain the demonstrations done in class. Seventy four percent of students indicated they visualized the animations while attempting to answer conceptual questions, or when they were reviewing concepts for a test or quiz. The percentage of the students that felt the computer animations helped them understand the gas laws and the relationships between the four variables of any gas was eighty five percent. The portion of students that felt they would not have achieved the level of understanding they did without the use of animations was eighty three percent. Finally, eighty percent of students felt that some animations used made a concept clearer than any amount of lecture could have. The complete survey is included in Appendix B.

Table 4

Gas Law Unit Survey: Student Reaction to the Use of Animations

Statement	Percentage of Students that Agreed With the Statement	
	Scored 5 or Higher	Scored 7 or Higher
A	.96	.80
B	.91	.72
C	.85	.72
D	.85	.72
E	.80	.43
F	.74	.48
G	.83	.65
H	.80	.61

Note. Scale used: 1- Strongly Disagree, 5- Agree, 10- Strongly Agree

Chapter 5

DISCUSSION

Contributions of This Study

Through completion of this study, the author has assembled a web page including a variety of computer animations that target the key concepts pertaining to kinetic theory, properties of gases and gas laws to a degree of depth and breadth consistent with an introductory high school level chemistry class. Due to school district policy, the web page may only be posted on the district intranet. Teachers in the district are made aware of resources such as these on days committed to professional growth. Currently, any instructor in this suburban school district can access this itemized collection of computer animations to further assist their students in understanding the properties of gases, gas laws and the relationships between gases at the microscopic and macroscopic level. It is through these computer animations that students can begin to “see” the illusive microscopic level of chemistry. Through developing a better understanding of chemistry at the microscopic level, students can begin to understand why larger observable macroscopic events take place. Specifically, students can begin to understand how the activity and interaction of molecules and atoms explains observable phenomena. The results of this research project imply that students can improve their understanding of the relationship between the microscopic and macroscopic level of gases through the use of computer animations.

A Review of the Problem and Purpose of This Study

The central problem that motivated the author to pursue this study is that the field of chemistry is abstract in nature. Chemical interactions at the atomic or molecular level cannot be seen. As a result, students often fail to fully comprehend many of the concepts that they study. Students struggle with chemical interactions or events occurring at the microscopic level, and how these events relate to larger observable macroscopic phenomena (Johnstone, 1993; Kozma, 1997; Wilensky, 1999 & Wu, 2001).

The traditional approach to teaching chemistry involves three levels of description: *microscopic, macroscopic and representational* (Johnstone, 1993). The *macroscopic*, or observable events, and the *representational*, including graphs, chemical symbols and chemical reactions, are the main focus of many high school chemistry courses because of the obvious difficulty the *microscopic* level presents (Wilensky, 1999). The *microscopic* level, defined as atomic and molecular interaction, is equally important, however there has been no way to convey what is happening at this level other than to interpret the representational graphs and mathematic analysis in the context of observable macroscopic events. To be an effective student in comprehending the *microscopic* level, strong math skills and the ability to correctly interpret mathematical analysis is required. Typically, the successful chemistry student is one that can generate a mental image of the molecular or atomic processes taking place in accordance with a graph or set of values generated through analysis (Wu, 2001 & Kozma, 1997). Another tool that may be used to understand or predict what is happening at the *microscopic* level is to apply a theoretical set of rules that governs the behavior and interaction of particles of matter. The study of the behavior of large numbers of molecules each following individual rules of motion is known as statistical mechanics. However, Wilensky (1999) describes the difficulty most people have with statistical thinking. Historically, the *microscopic* level has even been omitted from some high school curriculum because of the difficulties students have with attempting to understand and visualize microscopic processes (Wilensky, 1999).

In summary, the fundamental problem of learning chemistry is that the student needs to have a basic level of understanding of all three levels, the *microscopic, macroscopic and representational*, in order to avoid building an inaccurate schema as a result of an incomplete and thus skewed understanding of chemical processes and concepts. Specifically, this applied project addressed the difficulty students have with applying the rules of kinetic theory of gases to the behavior of a real gas sample. Kinetic theory describes how the particles (atoms or molecules) of a gas behave. The macroscopic observable behavior of the gas sample students can see emerges *as a result* of the gas particles interaction as per the rules of kinetic theory. Applying kinetic theory successfully implies that a student can visualize the interaction between and behavior of the particles of a gas. This is the first step to understanding and being able to predict how the behavior of particles is connected to observable macroscopic behavior of a gas sample.

The purpose of this study was to establish whether or not using animations would increase students' learning and comprehension of microscopic events occurring in gasses, and whether or not using animations would help students to develop the ability to comprehend how these microscopic events are related to macroscopic events. The hypothesis of this study stated that students having the opportunity to visualize gases at the atomic and molecular level through computer animations would demonstrate an increased ability to answer subjective and objective questions requiring comprehension of the behavior of gas particles and the resulting emergent properties of gases. Results of this study were not conclusive. The p values from analysis of the first assessment indicated a significant statistical difference existed between Group A and Group B. However, analyses of successive assessments generated p values just larger than .05 and were therefore not technically statistically significant. Never the less, the author contends that acceptance of the hypothesis is legitimate, and that the purpose behind the project has also been fulfilled. Results of this study do appear to support the conclusion that the use of animations can increase students' learning and comprehension of microscopic events occurring in gasses, and help students to develop the ability to comprehend how these microscopic events are related to macroscopic events.

Interpreting the Results of Assessments and the Survey

It is important to recognize that the two populations of students used through out this study were not statistically different in terms of their academic abilities. The *p* value comparing their previous semesters grades and a previous unit exam were .42 and .56 respectively. The *p* value would have to be smaller by roughly a factor of ten in order to consider the academic differences between these two groups on these two assessments to be statistically significant. The results of these T-tests allows for the acceptance of the assumption of heterogeneity between Group A and Group B. In addition, the size of each group was significant at 50 for group B, and 48 for Group A. A relatively large sample size increases the precision of all T-test run throughout this study.

A comparison of Group A's and Group B's performance on the initial assessment, "Properties of Gases Quiz", showed a statistically significant *p* value of .044. Specific questions appearing on this quiz were chosen by the author because answering these questions required the application of kinetic theory. These questions are asterisked on the assessment found in appendix A and are labeled as "Selected questions" in Table 2. Comparison of the two group's performances on these selected questions shows a *p* value of .001, which is a highly statistical difference. These questions either required the student to correctly describe how gas particles would behave according the rules of kinetic theory, or the question required the student to predict how a gas sample might change according to specific influences. For example, true or false question #19 states, " If a gas sample of pure Helium is at constant temperature, then all the atoms of Helium making up the gas sample will be traveling at the same speed". The relevant portion of kinetic theory that is useful in answering this question states that the average kinetic energy (KE) of particles is proportional to temperature. The key word here is *average*.

To the students in Group A that simply read or heard this portion of kinetic theory, the concept of average was probably not processed. These students most likely visualized all the Helium atoms moving at the same speed due to the constant temperature, which is why they marked this statement incorrectly as "true". However, the students in Group B that had the benefit of seeing an animated gas sample were most likely immediately aware of the key concept of average in this case. In the animation, Helium atoms are depicted moving at different speeds despite a constant temperature. Further, when a slow moving atom is struck by another atom that is moving at a faster rate of speed, the energy of the fast moving atom may be transferred to the slow moving atom. The result is the previously fast moving atom is now moving slowly, while the just energized atom takes off with much greater speed. Having seen this, students quickly understand the significance of the word *average* in this statement of kinetic theory. Specifically, the temperature of a gas sample is a measure of the average KE of all particles making up a gas sample.

Examples of questions requiring students to predict how a gas sample might change due to specific influences are #28 through #32. Students are asked to predict if the volume of a balloon will increase, decrease, or remain constant given specific conditions. It is important to note that all students in both Groups A and B witnessed demonstrations nearly identical to the scenarios presented in these questions. However, students exposed to animations, Group B, performed statistically better than students in Group A. Group A simply saw the demonstrations but had no visual reinforcement as to the behavior of the particles inside the balloons that ultimately explains the final state of the gas sample inside the balloon. These questions focused on the concept of pressure. Being able to correctly visualize pressure, that is the force particles exert as they collide with the walls of their container, may be a result of seeing animations and probably moves the concept of pressure from abstract to more concrete for many students.

It is the author's opinion that the ability to accurately visualize a gas sample and the behavior of the particles making up the sample is greatly enhanced through the use of animations. The specific questions I chose to discuss previously are not unique. To answer any of the selected questions from all of the assessments administered throughout this unit, students need to be able to accurately visualize a sample of gas. Specifically, the student needs to be able to visualize the activity and interaction of the particles of the gas. The rules of kinetic theory were introduced to all students in Groups A and B. The same demonstrations were also shown to all these students to illustrate specific rules of kinetic theory and various properties of gases. To fully process this information, students must build their own schemata, or knowledge structure. However, since chemistry is a new field to these students and their background knowledge is limited, their schemata that they assemble may be incomplete, inaccurate, or both.

Concepts that students are exposed to and demonstrations they witness may not be interpreted correctly. Group A's assessment results appear to support this trend. In the opinion of this author, which is corroborated by ChanLin (1998), animations have a powerful ability to assist students in interpreting demonstrations or events and processes correctly which then help students to form accurate schemata. ChanLin points out that animations serve as an interpretation model and can assist students in accurate shemata formation by compensating for a lack of background knowledge (1998). Hays(1996) states that when learning requires visualizing a dynamic process or an understanding of how motion relates to a concept, animations do seem to help the learner.

In addition to computer animations apparent ability to help learners form correct schemata, Pavio's dual-coding theory suggests another reason why students seem to benefit from computer animations. Dual-coding theory claims that students code and store information in long-term memory in two different ways, a verbal code and a visual code. These two different modes of processing information are additive and reinforce one another. When information is coded both verbally and visually, the information is twice as likely to be remembered (Rieber, 1996). Verbal information tends to be coded verbally only, whereas visual information is more likely to be coded dually; both verbally and visually. Hence, the results of this study and research by Reiber (1991) indicate that teaching with visuals, such as computer animations, results in greater retention of material.

Kozma (1997), Pence (1993) and Wu (2001) have all concluded that using more visual imagery in class will help to improve the student's proficiency at visualizing chemical principles. Hays (1996) claims computers animations possess two unique qualities that allow them to show concretely the visualizations required in order to form accurate conceptual representations. These unique qualities are the tendency for computer animations to be coded dually, and their ability to facilitate accurate schemata formation. The author believes these two qualities of computer animations to be the essential explanation as to why computer animations appeared to benefit the students in this study. The results of the survey overwhelmingly indicated that students believed the computer animations were helpful. The fact that students agreed that the computer animations made concepts easier to understand, and that they found it helpful to visualize some of the animations while trying to understand demonstrations, study, or answer conceptual questions, validates the previously mentioned research. Students do appear to benefit from the use of animations. An added benefit of using computer animations may be that their use motivated students to want to learn the particular topic. Rieber (1991) claims computer animations may be appealing and intrinsically motivating to students.

Limitations

As stated earlier, the results of this study were promising, but not conclusive. Table 2 shows the p values for all assessments given, as well as analysis of selected questions targeting the application and interpretation of kinetic theory for each assessment. After the first assessment, "Properties of Gases Quiz", none of the p values listed were technically statistically significant although *p* values did not exceed the cut-off for significance (.05) by more than .16. The pattern that appears from the "Selected questions" from the "Kinetic Theory: Shot Answer Quiz" through the remaining assessments, is one that shows a slow but steady increase in *p* values. In other words, the statistical significance between the two groups became less and less over time. The author attributes this to the fact that after each assessment students of both groups were tutored during a post-test session. The most frequently missed questions were targeted, and incorrect student responses were discussed as to what the correct responses to questions were and why they were correct. Flaws in reasoning and common misconceptions were discussed. It is possible that students were able to review and correct their schemata, or knowledge structure, as a result of these post-test sessions. This would certainly reduce the number of incorrect responses by students of both groups on future assessments thereby resulting in statistically insignificant *p* values.

This study was carried out in a classroom setting, and the primary objective in the classroom is to educate students. Therefore, the author tutored Group A students extensively to help them gain an understanding of the material presented in class. As a result of working with both groups of students, the author became acutely aware of the flaws in reasoning and the misconceptions that Group A was experiencing. Educational objectives were revised and made more specific based on an improved understanding of these flaws in reasoning and misconceptions experienced by Group A students. Tutorial sessions with Group A students became more effective due to the authors opportunity to compare what concepts Group B students did understand and the concepts Group A students did not understand. Hence, a potential limitation of this study may be that the author could have been working towards diminishing the beneficial impact of computer animations. Moreover, Group B may have had the benefit of computer animations, however Group A benefited from carefully crafted lectures, demonstrations and explanations to target these specific weaknesses in comprehension as the author became aware of them.

The author stated previously that in order for students to answer any of the selected questions correctly from all of the assessments administered throughout this unit, students needed to be able to accurately visualize a sample of gas. Although this ability to correctly visualize a gas sample is very helpful, basic gas laws, such as Boyle's law, Charles' law, or Guy Lussac's principle, can also be used to predict the behavior of a gas sample undergoing specified changes. The author introduced these gas laws to students two days before the second assessment "Kinetic Theory: Short Answer Quiz". Utilizing these gas laws to answer selected questions on the last three assessments could have certainly reduced the significance of computer animations. For example, a question on the unit exam describes a sample of gas in a sealed, rigid container in which the pressure goes down. The student is asked for the most likely explanation. Visualizing the particles of the gas sample and employing kinetic theory, one could attribute the pressure decrease to the fact that particles must be slowing down, colliding with the walls of the rigid container less frequently. The temperature, and therefore speed of the particles, must be going down. However, recognizing that the constants of the gas described in the question are volume and number of particles, pressure and temperature must be variable. The student can then apply the appropriate principle, Guy-Lussac's principle, recognizing that the relationship between pressure and temperature for a fixed number of particles at a constant volume is a direct proportion. Therefore, if the pressure is dropping in this rigid, sealed container, the temperature must also be going down.

Some students prefer to actually generate their own hypothetical values, insert them into the appropriate equation and solve for the unknown. This problem solving technique is not dependent upon the ability to visualize a gas, but to isolate variables and employ a mathematical relationship. Since most students making up the population involved in this study were reasonably proficient in basic algebra, this problem solving technique was attainable to them once they were exposed to the basic gas laws. This is an example of the type of instruction the author utilized to enable Group A students to be successful. This alternate method of reasoning represents a limitation to this study, as this alternate instruction was utilized specifically to allow students to be successful without the benefit of visual imagery.

Future Research

Existing literature, as well as the results of this study, supports the use of animations in teaching concepts that require the student to generate an accurate mental image of an event or a process. However, several questions remain. Future study could focus on what a good animation looks like, specifically qualities or characteristics identifying what makes an animation effective. Determining the most effective point at which animations are introduced in the delivery of a concept should be explored. Is it most effective to show animations before, during or after, a concept is taught? Alternatively, is it most advantageous to use the same animation numerous times through out a lesson? The limitations of animations should also be explored. Is there an amount of time animations should be limited to? Animations may be helpful in demonstrating laboratory procedures, however to what degree should animations be used to demonstrate or even replace laboratory experiments? Finally, a question raised that is particularly pertinent to the results of this study, do animations significantly increase students' understanding of a concept, or simply help students attain a given level of comprehension faster? A technique allowing educators to help students learn concepts more quickly and perhaps more thoroughly would be of great interest.

Summary

The intent of this study was to establish whether or not computer animations could be used to enhance students' comprehension of the properties of gases, gas laws and kinetic theory. Two groups of students were given identical assessments and their scores were collected and analyzed using T tests. One group was taught using computer animations, while the other group was taught without them. The results of this study suggest that students' comprehension of the properties of gases, gas laws and kinetic theory is increased through the use of animations. The power of animations in this study most likely resided in their ability to assist students in properly visualizing the processes and events that occur in gases.

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APPENDIX A

Assessments

Properties of Gases Quiz

True or False:

1. Gases will seek maximum entropy.

2. The temperature of a gas and the kinetic energy of a gas are not proportional.

3. Some gases do not exert any pressure.

4. An “ideal gas” does not exist.

5. Real gases behave like “ideal gases” as long as real gases are not exposed to extreme conditions such as very low temperatures or very high pressures.

6. According to the kinetic theory model of gases, all collisions between particles are perfectly elastic.

7. Entropy is a measure of disorder.

8. You have a fixed number of particles in a rigid container. If the particles move faster, the pressure in the container will increase.

9. At the <u>beginning</u> of ACT 3-3 where H_2 gas was in one test tube and air was in another, entropy was high.

10. In Act 3-2, water was kept inside the upside down test tube due to atmospheric pressure.

11. Any gas sample contains a lot of empty space compared to a solid or liquid.

12. Gases of different molecular masses will settle out in layers much like liquids of different densities.

Regarding the Live Demo: questions 13 through 15

13. A pressure change occurred . . . (mark all that apply)

    a. in the bucket
    b. at the end of the swinging hose
    c. no pressure changes occurred at either end.

True or False:

14. The greatest pressure would be at the end of the hose that is in the bucket.
15. The live demo and the story below both have the same explanation.

    While driving down the highway, a wasp suddenly appears in your car. You open the window slightly, and the wasp is ejected out through the opening onto the highway.

*16. Vapor pressure of a liquid is the pressure exerted by the molecules of that liquid once they have evaporated.

17. The boiling point of a liquid will increase as elevation increases.

*18. If you increase the pressure on a gas sample by decreasing the volume, the gas particles will speed up.

*19. If a gas sample of pure Helium is at a constant temperature, then all the atoms of Helium making up the gas sample will be traveling at the same speed.

*20. At a fixed temperature, the speed of a particle will depend upon its mass.

*21. The average speed of two unlike gas particles before a collision is equal to the

*22. If a mixed sample of gas, like air, is at a constant temperature, then all the particles of the gas sample are moving at the same speed.

Multiple Choice:

23. As you go higher in elevation while climbing Mt. Everest

    a. the % oxygen in the air decreases quickly.
    b. the amount of oxygen in the air decreases.
    c. the amount of oxygen in the air remains the same.
    d. none of the above statements are correct.

24. The constant bombardment of the walls of a container by the moving molecules of gas produces the characteristic called:

    a. temperature   b. density   c. diffusion   d. pressure

25. As the temperature of a gas increases, the particles of the gas

a. lose kinetic energy
b. increase in mass
c. increase in speed
d. collide less frequently

*26. Diffusion between two gases will occur most rapidly if the two gases are at a

a. low temperature and the molecules are large
b. high temperature and the molecules are small
c. low temperature and the molecules are small
d. high temperature and the molecules are large

*27. Suppose that two gases with unequal molecular masses were injected into opposite ends of a long tube at the same time and allowed to diffuse toward the center. They should begin to mix

a. at the end that held the heavier gas
b. closer to the end that held the heavier gas
c. closer to the end that held the lighter gas
d. at the end that held the lighter gas
e. exactly in the middle

Use the choices below to answer questions 28 through 32 .
A balloon will experience various changes as described in each question. You decide how the balloon will change, if at all.

A. the volume of the balloon will increase
B. the volume of the balloon will decrease
C. the volume of the balloon will not change

*28. the balloon is heated but no outside pressure(pressure of the room) is changed.

*29. additional particles are injected into the balloon

*30. the outside pressure is doubled.

*31. the outside pressure is lowered.

32. The incident at Lake Nyos best illustrates what property or law of gases

   a. gases diffuse rapidly
   b. gases seek maximum entropy
   c. both a and b
   d. all gases have mass.

* indicates this question was considered a higher order thinking question. These questions were analyzed separately. The resulting *p* value from the analysis of these questions appears in table 2 labeled “Selected questions”.

Kinetic Theory: Short Answer Quiz

*1. The pressure exerted by a gas particle depends on two factors. List them:

a. ___________________________

b. ___________________________

*2. Consider all four variables of any gas. How could you increase the pressure of a gas sample? List 3 ways to accomplish this.

a. ____

b. ____

c. ____

*3. How is it that water will evaporate at room temperature?

NASA engineers select materials for spacecrafts that do very little **outgassing**. **Outgassing** is the process of gaseous molecules within a material leaving the material and diffusing into the atmosphere.

4. **Why** would various materials tend to outgas in space? Be as brief and concise as you can.

* indicates this question was considered a higher order thinking question. These questions were analyzed separately. The resulting *p* value from the analysis of these questions appears in table 2 labeled “Selected questions”.

Kinetic Theory: Short Answer Quiz Rubric

*Pressure factors @ constant temperature:

Mass	____	1 pt
Velocity	____	1 pt

*Increase the pressure of a gas sample?

Inc. Temp	____	1 pt
Inc. # of Particles	____	1 pt
Decrease Volume	____	1 pt

*How is it that water will evaporate at room temperature?

Not all particles are traveling at the same speed, **KE's vary**	____	1 pt
Some particles have a **high enough KE** to escape liquid and become gaseous	____	1 pt

Why would various materials tend to outgas in space?
(earn a max of 2 points)

Atm pressure is less in space	____	1 pt
Pres. of gas in materials exceed the pressure of space	____	1 pt
Low atm pres **increases rate of diffusion** (earn a max of 2 points)	____	1 pt

Score	____	pts
Total points possible	____	**9 pts**

Boyles's & Charles' Law: Short Answer

1. Which equation represents a <u>direct</u> proportion?
   a. A + B = k
   b. A x B = k
   c. A/B = k
   d. A - B = k   1_______
2. Convert the following temperatures:

   a. 36 C = ? K   2a_______

   b. 390 K = ? C   2b_______

3. A gas at 20 C and at a volume of 2 L is warmed to 7 C. What will the new volume be in liters ?(3a) What is this volume in milliliters? (3b)

3a_______

3b_______

4. 500 mL of a gas is at a pressure of 6 atm. If the pressure is changed to 4 atm, what will the new volume be in milliliters?(4a) What is the volume in liters?(4b)

4a_______

4b_______

5. A gas is at 29.4 psi and in a container that holds 3 L. If the gas is placed into a 5 L container, what will the final pressure be psi?(5a) What is the final pressure in mmHg?(5b)

5a_______

5b_______

6. Draw a simple graph. Label the **x** and **y axis** with the **correct variable** and draw the typical **curve or line** for **Boyle's law.**

7. You pour yourself a tall glass of soda. Because the soda was in the refrigerator, it is at a uniform temperature. As you watch the bubbles attached to the bottom of the glass rise to the top of the glass, the bubbles appear to become larger in size. Could your observations be correct?(7a)

7a. yes no

Breifly explain **how each variable is changing** during the scenario above:
(I = increasing, D = decreasing, C = constant)

a. Pressure — a. I D C

b. Temperature — b. I D C

c. Volume — c. I D C

d. # of particles — d. I D C

e. What gas law, if any, is helpful in analyzing this scenario? e.___________

8. Suppose we have a balloon that is being heated while the pressure remains constant. What will happen to the volume of the balloon as the temperature rises? (8a)

8a.____

8b. Through out the heating process, how is it that pressure remains constant even though temperature is increasing? Be as specific as possible. You may use pictures to enhance your answer, but you must explain your drawings.

Gas Law Exam

*1. Absolute zero is equal to:

a.-760 ^{o}C b. -273 ^{o}C c. 0.01 ^{o}C d. -273 ^{o}F

2. A sample of gas in a sealed container at a constant volume experiences a drop in pressure of 75 mm Hg. The most likely explanation is that

a. the container exploded
b. the temperature increased
c. the temperature decreased
d. more particles are present

3. Which of the following variables must be constant in order to use Boyle's law? You **must** mark more than one answer.

a. P b. V c. T d. number of particles

*4. Diffusion between two gases will occur most rapidly if the two gases are at a

a. Low temperature and the molecules are large
b. High temperature and the molecules are small
c. Low temperature and the molecules are small
d. High temperature and the molecules are large

5. The incident at Lake Nyos best illustrates what property or law of gases
a. Boyle's law
b. Charles' law
c. Entropy
d. All gases have mass.

6. A test tube filled with 0.95 grams of steel wool and air is inverted in water. The water level rises into the tube 3.20 cm. The length of the test tube is 14.40 cm. What is the % oxygen in this air?
a. 28.60 % b. 11.2 % c. 14.4 % d. 22.2 %

*7. Suppose that two gases with unequal molecular masses were injected into opposite ends of a long tube at the same time and allowed to diffuse toward the center. They should begin to mix

a. at the end that held the heavier gas
b. closer to the end that held the heavier gas
c. closer to the end that held the lighter gas
d. at the end that held the lighter gas
e. exactly in the middle

8. Which of the following variables must be constant in order to use Charles' law? You must mark more than one answer.

a. P b. V c. T d. number of particles

*9. Using concepts from Graham's Law, which gas, SO_2 or CH_4, will travel faster and why? Assume gases are at equal temperatures.

a. SO2 travels faster because it has fewer atoms
b. CH4 travels faster because it has a smaller molecular mass
c. SO2 travels faster because it has a smaller molecular mass
d. CH4 travels faster because it is less dense
e. If the gases are at equal temperatures, then their kinetic energies and therefore speeds will be equal.

Use the choices below to answer questions 10 through 13.
A balloon will experience various changes as described in each question. You decide how the balloon will change, if at all.

A. the volume of the balloon will increase
B. the volume of the balloon will decrease
C. the volume of the balloon will not change

*10. The balloon is heated but no outside pressure (pressure of the room) is changed.

*11. The balloon's temperature is doubled and the outside pressure is doubled.

*12. The outside pressure is doubled.

*13. The outside pressure is lowered.

----

14. When doing the " % oxygen in air lab", assume you arrived at a value of 18.7% oxygen in air. The accepted value is 20.4% oxygen in air. What is your % error?

a. 1.1%   b. .92%   c. 8.3%   d. -8.3%

15. In reference to question 14 about the " % oxygen in air lab", which is NOT a possible source of error? **Consider the values given in question 14.

a. The acid bath used to treat the steel wool was too weak.
b. The steel wool was too compact, creating minimal surface area.
c. Air was lost out of the test tube when the experiment was started.
d. The time the experiment had to run was too short.

16. Which of the following variables must be constant in order to use Guy Lussac's law? You must mark more than one answer.

a. P   b. V   c. T   d. number of particles

*17. The constant bombardment of the walls of a container by the moving molecules of gas produces the characteristic called:

a. temperature   b. density   c. diffusion   d. pressure

*18. As the temperature of a gas increases, the particles of the gas

a. lose kinetic energy   b. increase in mass
c. increase in speed   d. collide less frequently

*19. As you go higher in elevation while climbing Mt. Everest,

a. the % oxygen in the air decreases quickly.
b. the amount of oxygen in the air decreases.
c. the amount of oxygen in the air remains the same.
d. none of the above statements are correct.

*20. If five different gases in a cylinder each exert a partial pressure of 2.5 atm , what is the total pressure exerted by the gases?

a. it is exactly the same, 2.5 atm.
b. it is the total pressure minus 2.5 atm.
c. it is 2.5 atm times 5.
d. it is the total pressure divided by 2.5.

21. The idea that the total pressure of a mixture of gases is the sum of their partial pressures was proposed by

a. Charle's b. Boyle's c. Kelvin d. Dalton

22. 363 K would be equal to how many degrees Celsius?

a. 273 ^oC b. 90 ^oC c. 32 ^oC d. 0 ^oC

23. Standard temperature is exactly:

a. 100 ^oC b. 0 ^oC c. 273 ^oC d. 0 K

24. While vacationing in Mexico, you go diving. If you dive to a depth of 20 m, you would experience a pressure of . . .(every 10 m of water exerts 1 atm)

a. 4 atm
b. 3 atm
c. 2 atm
d. 1 atm
e. This is not possible to answer because we do not know what the

25. Suppose a diver 200 ft under water swims to the surface quickly. Which statement most accurately describes the divers fate?

a. He will be fine as long as he exhales the expanding gas in his lungs.
b. He will be fine as 200 ft isn't deep enough to cause a harmful pressure change.
c. He will be crushed as he ascends to the surface too quickly.
d. Even if he exhales the expanding gas in his lungs, the gas dissolved in his tissues will expand causing severe internal damage.

26. The story in question number 25 describes a condition referred to as

a. the bends.
b. compresion sickness
c. “rapture of the depths”
d. diver’s delerium

27. All of the following situations can be explained by Bernoulli’s Principle EXCEPT,

a. cigarette smoke getting “blown” out through a cracked car window while driving.
b. an airplane takes flight.
c. a pitcher throws a curve ball.
d. All of the above are examples of Bernoulli’s Principle

28. The solubility of any gas in water increases as the temperature of the water

a. decreases
b. increases
c. there is no simple relationship between temperature and solubility of a gas

Use the space provided to show all your work with units. Avoid simple mistakes!!

29. The initial pressure of a gas is 800 torr at 27 oC in a 3.0 Liter weather balloon. What is the new pressure if the temperature is 54oC and the volume of the gas is 4.2 Liters?

a. 437 torr　　b. 343 torr
c. 977 torr　　d. 623 torr

30. If the temperature of a gas is -35 oC, when the volume is 300 mL, what will the temperature need to be changed to so that the volume of the gas is 600 mL?

a. 119 ^{o}C　　b. 476 ^{o}C　　c. 203 ^{o}C　　d. -154 ^{o}C

31. If a gas at 500 torr and 10 degrees celcius has a volume of 2.5 L, what will the volume be if the temperature is changed to 30 degrees celcius and 13 psi?

a. 558 ml　　b. 1250 ml　　c. 1029 ml　　d. 1992 ml

32. A balloon filled with 4.5 Liters of helium at room temperature (25 ^{o}C) is placed in contact with liquid nitrogen that has a temperature of -196 ^{o}C. What will the final volume of the helium balloon be?

a. 1.16 Liters　b. 2.3 Liters　c. 17.4 Liters　d. 35.2 Liters

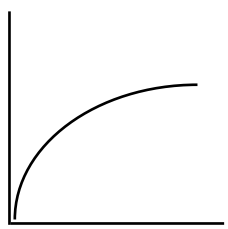
33. A 360 mL sample of hydrogen gas is collected when the pressure is 800 mm Hg. What is the volume that the gas will occupy when the pressure is lowered to 720 mm Hg?

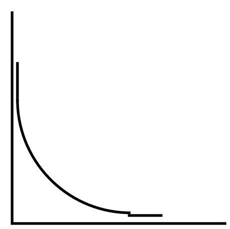
a. 400 mL b. 4.0 L c. 400 L d. 324 mL

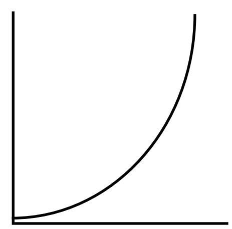
34. The volume occupied by a gas sample at 20psi is 4 L. What will the volume become if the pressure is changed to 2 atm?

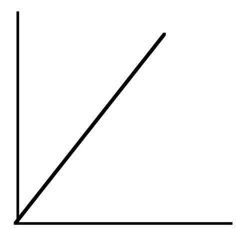
a. 2.7 L b. 40 L c. 5.9 L d. .4 L

Questions 35 - 38
Below are listed laws or a set of variables. Pick the graph that best represents each law or set of variables. You may use each choice more than once, but there is only one answer for each question.

A. 

B. 

C. 

D. 

*35. Charles' Law
*36. Boyle's Law
*37. Solubility of a gas in water vs. Temperature of the water the gas is dissolved in.
*38. Rate of diffusion of a gas vs. Size of the gas particles

39. When liquids are under high pressure, the solubility of a gas in the liquid is________. This is known as _____________.

a. increased ; Henry's Law
b. increased ; Joule -Thompson effect
c. decreased ; Henry's Law
d. decreased ; Joule -Thompson effect

40. Generally, as gases expand, they tend to _________. This is known as _______________ .

a. cool ; Henry's Law
b. cool ; the Joule -Thompson effect
c. heat up ; Henry's Law
d. heat up ; the Joule -Thompson effect

41. A good example of Joule -Thompson effect at work would be

a. the ability to fill a tire with a small container of compressed air.
b. being able to dissolve more gas in a cooler liquid.
c. how the compressor in any refrigerator works to keep the inside of the refrigerator cold.
d. the fact that moving air exerts less pressure than still air.

* indicates this question was considered a higher order thinking question. These questions were analyzed separately. The resulting *p* value from the analysis of these questions appears in table 2 labeled "Selected questions".

APPENDIX B

Student Survey

Gases Unit Survey: Impact of Animations

Assign each statement a score of 1 to 10. Use the following scale when answering these questions.

1 Strongly Disagree
5 Agree
10 Strongly Agree

A. Overall, I found the animations to be helpful in understanding the topics addressed during the unit on gases.

B. The animations helped make the information presented during the lecture, "Properties of Gases", easier to understand.

C. When working to understand and explain the demonstrations done in class, I found it helpful to visualize the animations that were presented in class.

D. The animations helped me to understand the gas laws (Boyle's, Charles', Guy Lussac's, or Avogadro's principle), and how the four variables of any gas are related to one another.

E. When I answered conceptual questions asking me to predict how a gas sample would be altered according to specific changes in temperature, volume, pressure or number of particles, I thought about and/or visualized some of the animations used during class.

F. When I studied for quizzes and the gas exam, I found myself thinking about the animations to reinforce concepts, like pressure, the relationship between kinetic energy and temperature, or the relationship between the size of a particle and it's speed.

G. My level of understanding of gases and gas laws was improved through the use of animations. In other words, I don not think I would have achieved the level of understanding I did without the computer animations.

H. During this unit, one or more animations used made a concept clearer to me than any amount of lecture, description or reading on the topic could have.