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The Impact of Teacher Assigned but Not Graded Compared to Teacher Assigned and Graded Chemistry Homework on the Formative and Summative Chemistry Assessment Scores of 11th-Grade Students with Varying Chemistry Potential

Jennifer L. Wilson

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The Impact of Teacher Assigned but Not Graded Compared to Teacher Assigned and
Graded Chemistry Homework on the Formative and Summative Chemistry Assessment
Scores of 11th-Grade Students with Varying Chemistry Potential

By

Jennifer L. Wilson

A Dissertation

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Doctor of Education

In Educational Administration

Omaha, Nebraska

2010

Supervisory Committee

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Abstract

THE IMPACT OF TEACHER ASSIGNED BUT NOT GRADED COMPARED TO
TEACHER ASSIGNED AND GRADED CHEMISTRY HOMEWORK ON THE
FORMATIVE AND SUMMATIVE CHEMISTRY ASSESSMENT SCORES OF 11TH-
GRADE STUDENTS WITH VARYING CHEMISTRY POTENTIAL

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Advisor: Dr. John W. Hill

The study analyzed 2005 posttest data compared to 2008 posttest data to determine student end of school year academic achievement outcomes across three academic levels (above average, average, and below average chemistry potential) and two teacher homework evaluation methods (assigned but not graded and assigned and graded) on teacher prepared 11th-grade assessments, district prepared 11th-grade assessment, and district graduation requirement physical science strand 11th-grade science Essential Learner Outcome assessment. Overall, results indicated that students with above average ($n = 16$), average, ($n = 17$) and below average ($n = 14$) chemistry potential whom were given teacher assigned and graded chemistry homework compared to students with above average ($n = 17$), average ($n = 15$), and below average ($n = 19$) chemistry potential whom were given teacher assigned but not graded chemistry homework had statistically significantly higher independent t test matter homework scores while atoms, naming, and reactions homework scores were generally in the direction of higher but not significant scores for students given graded homework regardless of their chemistry potential. Furthermore, students of above average and below average chemistry potential who were

given assigned and graded chemistry homework performed statistically significantly better on the 11th-grade district prepared chemistry final and the district prepared physical science strand Essential Learner Outcome assessment *t* test results compared to students with the same chemistry potential given assigned but not graded chemistry homework, suggesting that the graded chemistry condition may have contributed to improved long term learning and retention of chemistry knowledge. Finally, the coefficient of determination ($r^2 = .95$) measure of strength of relationship between not completing, not graded chemistry homework and a corresponding drop in chemistry assessment scores for all students was 95% and the coefficient of determination ($r^2 = .82$) measure of strength of relationship between not completing, graded chemistry homework and a corresponding drop in chemistry assessment scores for all students was 82%. While not implying causality the study findings suggest that students who complete more homework, not graded or graded, have a higher probability of improving their chemistry assessment scores regardless of their chemistry potential.

Acknowledgements

I dedicate my doctoral dissertation to my grandma, Lola Lubbers. She has taught me the importance of strength and grace through all of life's challenges. I would like to express my appreciation to Dr. John Hill who served as my dissertation advisor. Dr. Hill was instrumental in helping me design, conduct, and complete my dissertation and I want to thank him for his support and encouragement. I would also like to thank the other members of my dissertation committee, Dr. Peter Smith, Dr. Neal Grandgenett, and Dr. Jody Isernhagen for their expertise and professionalism. Furthermore, I have been fortunate to have many other influential professors throughout my doctoral studies in the Department of Educational Administration and Supervision including Dr. Kay Keiser, Dr. Jeannie Surface, and Dr. Karen Hayes who all helped guided me through this life-changing process.

Throughout my eleven years as a teacher, I have been fortunate to work for the Omaha Public Schools, Boys Town High School, and most recently the Millard Public Schools. Working in these districts, I have gained a deeper understanding of education and a vast desire to help all students as they grow both academically and personally. My colleagues and students have taught me a lot about my educational beliefs and constantly rekindle my commitment to education.

I am blessed to have two fantastic children, Dylan and Lucas. Having children of my own deepens my desire to ensure education remains of the highest quality and my commitment to both my children and students motivates me to perform at the best of my ability every day. My commitment to education has been made easier by my husband Steve's complete understanding of my life as a teacher. I am grateful that Steve

encouraged me to go back to school so that I could achieve my academic dreams. He has been supportive of my passion and understanding of the time commitments that go with it. I thank him and love him for helping to make my dream a reality.

I am also thankful for the rest of my family. My parents, Brad and Bernie Lubbers, taught me the importance of education at an early age. Their unsurpassed work ethic and willingness to do anything for their children molded me into the person I have become. Their confidence that I could do anything I set my mind to helped push me to achieve all my dreams. My twin sister, Jessie and younger sister, Katie have encouraged and supported me in all my journeys. They have always been there for me and taught me that while work is important, it is just as important to enjoy life and celebrate one's accomplishments. I truly am blessed to have a great husband, children, family, and friends.

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CHAPTER ONE

Introduction

Literature Related to the Study Purpose

Many high school students have goals and dreams about careers in the health sciences and biological sciences as evident by the 107,000 members of Health Occupations Students of America in 2008-2009 (HOSA, 2010). Aspiring to have a career in the medical field is notable as it is foreseen there will be a large shortage in people qualified for such careers. The shortage is predicted to be quite large when one considers, for example, that approximately 10% of the current workforce in Northern Virginia is employed in health care and that by 2020, it is estimated that 40% of the workforce will have jobs related to health care (Gibbs, 2005). Furthermore, a shortage is predicted in the area of pharmacology and employment opportunities for pharmacists are expected to grow faster than many other professions in the coming decade (Wilbraham, Staley, Matta, & Waterman, 2005). Attaining a career in health care involves completion of rigorous science coursework at the high school level in chemistry, math, physics, and biology (Gibbs, 2005). Since Sputnik, the first Earth-orbiting artificial satellite was launched into elliptical low Earth orbit by the then Soviet Union on October 4, 1957, there has been a relentless emphasis on science and the importance of supporting student achievement in traditional hard science fields including math, physics, and chemistry (Gill & Schlossman, 2004). Chemistry has always been classified as a hard, rigorous science course; a course rich in context studying the never-ending realm of possibility and discovery in which over ten million man-made chemicals have already been

discovered and millions more are waiting to be analyzed by future scientists (Davis, Metcalfe, Williams, & Castka, 2002).

Because students' ability to comprehend science is essential to the future of our society it is important for teachers to evaluate their instructional methods when teaching difficult to master science coursework (Streitberger, 1985). Currently, American students are not competing well internationally in the area of science. For example, as recently as 2007, 4th-grade and 8th-grade students Trends in International Mathematics and Science Study results placed American students below countries such as Singapore, Japan, and England in measured science knowledge. In this study 4th-grade American students placed 8th out of 36 countries while 8th-grade American students placed 10th out of 48 countries (National Center for Educational Statistics, 2010). Furthermore, a comparison of the science scores of 15-year old students in 30 Organization for Economic Cooperation and Development (OECD) countries, conducted by the Program for International Student Assessment (2006) found that students in the United States scored below the international mean score on science information (National Center for Educational Statistics, 2010). This measured international science knowledge shortfall will make it more difficult for American students to prosper in our ever-shrinking science and technologically dependent world and compete academically and economically at the highest levels of science (Gibbs, 2005). More and more international researchers are contributing to leading United States clinical research journals wherein by the late 1980s approximately 25% of the papers published in the *New England Journal of Medicine* and 60% of the papers published in *Clinical Chemistry* were of non-United States representation (Bruns, 1990).

Without future scientific advancement, dependent on scientifically literate students, whom will be tomorrows' innovators and inventors, our nation's economic and social interests are at risk (Rabino, 1998). A solid science foundation must be in place for students to be successful (Barton, 2009). Whatever the students' area of science study or inquiry, it is asserted that only a solid framework of real world teacher driven demands will heighten students' motivation resulting in completion of assignments, understanding of laboratory techniques, reading beyond the textbook, and revering science history (Hurd, 1998).

Chemistry is considered a cornerstone of scientific knowledge and medical advancement. This understanding of chemistry has historically begun in high school as part of a rigorous series of college preparatory courses beginning with biology. One study found that schools offering in-depth courses in biology, chemistry, and physics better prepared students for college than schools offering a breadth of knowledge in various science areas as many times required by standard tests (Cavanagh, 2009). Other recent trends view the chemistry curriculum as conceptual, how chemistry pertains to a student's life, rather than academic, where understanding chemistry formulas and calculations are required, in a move to make this knowledgebase available to all high school students (Prescott, Rinard, Cockerill, & Baker, 1996). This change may result in improved science appreciation but a diminished chemistry foundation for students who want to pursue scientific university coursework and careers.

Purpose of the Study

The purpose of this study was to determine the impact of teacher assigned but not graded chemistry homework on the formative and summative chemistry assessment

scores of 11th-grade students with above average, average, and below average chemistry potential compared to the formative and summative chemistry assessment scores of 11th-grade students with above average, average, and below average chemistry potential who completed teacher assigned and graded chemistry homework assignments.

The study analyzed 2005 posttest data compared to 2008 posttest data to determine student academic achievement outcomes across three academic levels and two teacher homework evaluation methods on teacher prepared 11th-grade assessments, district prepared 11th-grade assessment, and district graduation requirement physical science strand 11th-grade science ELO assessment.

Research Questions and Data Analysis

The following posttest-posttest research question was used to analyze students with above average chemistry potential who were given teacher assigned but not graded chemistry homework and students with above average chemistry potential who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on teacher-prepared assessments.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #1. Do students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of the unit posttest 11th-grade chemistry scores as measured by the teacher prepared 11th-grade criterion-referenced tests (CRTs) for (a) matter, (b) atoms, (c) naming, and (d) reactions?

Sub-Question 1a. Are the teacher prepared posttest 11th-grade end of unit matter CRT assessment scores the same for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-Question 1b. Are the teacher prepared posttest 11th-grade end of unit atoms CRT assessment scores the same for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework and students with above average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-question 1c. Are the teacher prepared posttest 11th-grade end of unit naming CRT assessment scores the same for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework and students with above average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-question 1d. Are the teacher prepared posttest 11th-grade end of unit reactions CRT assessment scores the same for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework and students with above average chemistry potential who were given teacher assigned and graded chemistry homework?

The following posttest-posttest research question was used to analyze students with average chemistry potential who were given teacher assigned but not graded chemistry homework and students with average chemistry potential who were given

teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on teacher-prepared assessments.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #2. Do students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of the unit posttest 11th-grade chemistry scores as measured by the teacher prepared 11th-grade CRTs for (a) matter, (b) atoms, (c) naming, and (d) reactions?

Sub-Question 2a. Are the teacher prepared posttest 11th-grade end of unit matter CRT assessment scores the same for students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-Question 2b. Are the teacher prepared posttest 11th-grade end of unit atoms CRT assessment scores the same for students with average chemistry potential who were given teacher assigned but not graded chemistry homework and students with average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-question 2c. Are the teacher prepared posttest 11th-grade end of unit naming CRT assessment scores the same for students with average chemistry potential who were given teacher assigned but not graded chemistry homework and students with

average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-question 2d. Are the teacher prepared posttest 11th-grade end of unit reactions CRT assessment scores the same for students with average chemistry potential who were given teacher assigned but not graded chemistry homework and students with average chemistry potential who were given teacher assigned and graded chemistry homework?

The following posttest-posttest research question was used to analyze students with below average chemistry potential who were given teacher assigned but not graded chemistry homework and students with below average chemistry potential who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on teacher-prepared assessments.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement Research Question #3. Do students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of the unit posttest 11th-grade chemistry scores as measured by the teacher prepared 11th-grade CRTs for (a) matter, (b) atoms, (c) naming, and (d) reactions?

Sub-Question 3a. Are the teacher prepared posttest 11th-grade end of unit matter CRT assessment scores the same for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared

to students with below average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-Question 3b. Are the teacher prepared posttest 11th-grade end of unit atoms CRT assessment scores the same for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework and students with below average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-question 3c. Are the teacher prepared posttest 11th-grade end of unit naming CRT assessment scores the same for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework and students with below average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-question 3d. Are the teacher prepared posttest 11th-grade end of unit reactions CRT assessment scores the same for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework and students with below average chemistry potential who were given teacher assigned and graded chemistry homework?

The following posttest-posttest research question was used to analyze all students who were given teacher assigned but not graded chemistry homework and all students who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the district prepared assessment.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #4. Do all students who were given teacher assigned but not graded

chemistry homework compared to all students who were given teacher assigned and graded chemistry homework have congruent or different end of the unit posttest 11th-grade chemistry scores as measured by the teacher prepared 11th-grade CRTs for (a) matter, (b) atoms, (c) naming, and (d) reactions?

Sub-Question 4a. Are the teacher prepared posttest 11th-grade end of unit matter CRT assessment scores the same for all students who were given teacher assigned but not graded chemistry homework compared to all students who were given teacher assigned and graded chemistry homework?

Sub-Question 4b. Are the teacher prepared posttest 11th-grade end of unit atoms CRT assessment scores the same for all students who were given teacher assigned but not graded chemistry homework and students all students who were given teacher assigned and graded chemistry homework?

Sub-question 4c. Are the teacher prepared posttest 11th-grade end of unit naming CRT assessment scores the same for all students who were given teacher assigned but not graded chemistry homework and all students who were given teacher assigned and graded chemistry homework?

Sub-question 4d. Are the teacher prepared posttest 11th-grade end of unit reactions CRT assessment scores the same for all students who were given teacher assigned but not graded chemistry homework and all students who were given teacher assigned and graded chemistry homework?

The following posttest-posttest research question was used to analyze students with above average chemistry potential who were given teacher assigned but not graded chemistry homework and students with above average chemistry potential who were

given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the district prepared assessment.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #5. Do students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of the course posttest 11th-grade chemistry scores as measured by (a) the district prepared 11th-grade CRT?

Sub-question 5a. Are the district prepared posttest 11th-grade end of semester CRT assessment scores the same for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework?

The following posttest-posttest research question was used to analyze students with average chemistry potential who were given teacher assigned but not graded chemistry homework and students with average chemistry potential who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the district prepared assessment.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #6. Do students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework

have congruent or different end of the course posttest 11th-grade chemistry scores as measured by (a) the district prepared 11th-grade CRT?

Sub-question 6a. Are the district prepared posttest 11th-grade end of semester CRT assessment scores the same for students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework?

The following posttest-posttest research question was used to analyze students with below average chemistry potential who were given teacher assigned but not graded chemistry homework and students with below average chemistry potential who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the district prepared assessment.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement Research Question #7. Do students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of the course posttest 11th-grade chemistry scores as measured by (a) the district prepared 11th-grade CRT?

Sub-question 7a. Are the district prepared posttest 11th-grade end of semester CRT assessment scores the same for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework?

The following posttest-posttest research question was used to analyze all students who were given teacher assigned but not graded chemistry homework and all students who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the district prepared assessment.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #8. Do all students who were given teacher assigned but not graded chemistry homework compared to all students who were given teacher assigned and graded chemistry homework have congruent or different end of the course posttest 11th-grade chemistry scores as measured by (a) the district prepared 11th-grade CRT?

Sub-question 8a. Are the district prepared posttest 11th-grade end of semester CRT assessment scores the same for all students who were given teacher assigned but not graded chemistry homework compared to all students who were given teacher assigned and graded chemistry homework?

The following posttest-posttest research question was used to analyze students with above average chemistry potential who were given teacher assigned but not graded chemistry homework and students with above average chemistry potential who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the physical science strand of the science ELO.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #9. Do students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of district required science

outcomes posttest 11th-grade chemistry scores as measured by (a) the district graduation requirement physical science strand of the 11th-grade science ELO?

Sub-question 9a. Are the district graduation requirement physical science strand of the 11th-grade science ELO scores the same for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework?

The following posttest-posttest research question was used to analyze students with average chemistry potential who were given teacher assigned but not graded chemistry homework and students with average chemistry potential who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the physical science strand of the science ELO.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement Research Question #10. Do students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of district required science outcomes posttest 11th-grade chemistry scores as measured by (a) the district graduation requirement physical science strand of the 11th-grade science ELO?

Sub-question 10a. Are the district graduation requirement physical science strand of the 11th-grade science ELO scores the same for students with average chemistry potential who were given teacher assigned but not graded chemistry homework

compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework?

The following posttest-posttest research question was used to analyze students with below average chemistry potential who were given teacher assigned but not graded chemistry homework and students with below average chemistry potential who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the physical science strand of the science ELO.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement Research Question #11. Do students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of district required science outcomes posttest 11th-grade chemistry scores as measured by (a) the district graduation requirement physical science strand of the 11th-grade science ELO?

Sub-question 11a. Are the district graduation requirement physical science strand of the 11th-grade science ELO scores the same for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework?

The following posttest-posttest research question was used to analyze all students who were given teacher assigned but not graded chemistry homework and all students who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the physical science strand of the science ELO.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #12. Do all students who were given teacher assigned but not graded chemistry homework compared to all students who were given teacher assigned and graded chemistry homework have congruent or different end of district required science outcomes posttest 11th-grade chemistry scores as measured by (a) the district graduation requirement physical science strand of the 11th-grade science ELO?

Sub-question 12a. Are the district graduation requirement physical science strand of the 11th-grade science ELO scores the same for all students who were given teacher assigned but not graded chemistry homework compared to all students who were given teacher assigned and graded chemistry homework?

The following posttest-posttest research question was used to rank order correlate all students' not graded chemistry homework averages and graded chemistry assessment averages.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #13. What is the relationship between the Spearman rank order correlation coefficient of all students not graded chemistry homework averages and their graded chemistry assessment averages?

Sub-question 13a. Is there a significant relationship between the rank orders of all students not graded chemistry homework averages and graded chemistry assessment averages?

The following posttest-posttest research question was used to rank order correlate all students' graded chemistry homework averages and graded chemistry assessment averages.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #14. What is the relationship between the Spearman rank order correlation coefficient of all students graded chemistry homework averages and their graded chemistry assessment averages?

Sub-question 14a. Is there a significant relationship between the rank orders of all students graded chemistry homework averages and graded chemistry assessment averages?

Importance of the Study

This study contributes to research, practice, and policy. The study is of significant interest to teachers who are interested in finding out which homework method provides high achievement results and to secondary school leaders that are considering different grading methodologies in the hopes of raising school achievement.

Assumptions of the Study

This study has several strong features. All students in this study were enrolled in the research chemistry course from the beginning of the first semester 11th-grade through the end of the first semester 11th-grade in the research school. All study students were randomly assigned to the same chemistry course with the same chemistry teacher. Furthermore, all students had access to differentiated chemistry curriculum, instruction, and assignments based on each student's measured ability level and academic needs. In addition, all students within the study were assessed on all four teacher prepared first semester 11th-grade chemistry assessments, the district prepared first semester 11th-grade chemistry assessment and the district graduation requirement physical science

strand 11th-grade science ELO. Any student that did not complete all six of the above mentioned assessments was not included in the study.

The research school district Essential Learner Outcomes (ELO) science assessment consisted of test items and distracters written by highly qualified teachers in conjunction with curriculum supervisors and utilized the services of a contracted professional test item writer from outside the district. Once the ELO exam was generated, it underwent both pre-pilot and pilot testing to ensure test item quality. After the test pilot process was complete, groups of professional educators judged the assessment for curriculum alignment, test bias, and sufficiency of items in order to accurately diagnose students with ability levels as the below proficient, barely proficient, proficient, and beyond proficient levels.

Cutscores for all ELO exams were established using multiple methods to ensure accuracy. These methods included global rating, the Angoff method, and teacher professional judgment. These processes were carried out under the direction of Alpine Testing Solutions.

As required by district policy, the research school had re-teaching and remediation policies and procedures in place for all students who failed to score at the barely proficient level. All 11th-grade students who scored below proficient received re-teaching materials and assistance outside class time. This re-teaching may have occurred during study hall, guided study, before school, or after school.

Also required by district policy, all teachers in the research school had received Millard Instructional Model (MIM) training. A large piece of MIM was differentiation of

instruction. Teachers utilized MIM in their classrooms in order to meet the individual academic needs of all students.

Delimitations of the Study

The study findings, results, and discussions were delimited to the 11th-grade students of one high school in a suburban school district who were in attendance at the research school during the first semester of the 2005 school year or the first semester of the 2008 school year and were enrolled in the research chemistry course.

Limitations of the Study

This exploratory study was confined to one grade level of chemistry students enrolled in one chemistry section taught by the same chemistry teacher throughout the school day at the research school. Using the test results from one suburban high school chemistry course may have skewed the statistical results and reduced the utility and generalizability of the findings. Additionally, using students from two different school years may have resulted in selection bias as some students may have had more familiarity with assessments than the other group of students. Furthermore, the dependent variable was limited to chemistry achievement.

Definition of Terms

Above average chemistry potential students. Above average chemistry potential students are defined as students with an unweighted cumulative grade point average (GPA) of 3.3 or higher on a 4.0 scale at the end of the student's 10th-grade year. This GPA was chosen based on the 3.05 average GPA of all students in the study.

Amotivation. Amotivation is defined as neither intrinsic nor extrinsic motivation. An amotivated individual experiences feelings of incompetence and

perceives their behaviors as caused by forces out of their control (Ratelle, Guay, Vallerand, Larose, & Senecal, 2007).

Angoff method. The Angoff method is defined as a form of item analysis involving determining the likelihood of a minimally-competent student answering the question correctly in order to determine the cutscore for the exam (Brandon, 2002).

Average chemistry potential students. Average chemistry potential students are defined as students with an unweighted cumulative grade point average (GPA) between 2.86 and 3.3 on a 4.0 scale at the end of the student's 10th-grade year. This GPA was chosen based on the 3.05 average GPA of all students in the study.

Barely proficient rating. Barely proficient rating is defined as an indicator of a student's performance level on a particular criterion-referenced assessment based on an established cutscore. A student with a barely proficient rating, scores within a range of scores just above the lowest cutscore on a multi-level proficiency scale. Students scoring in this range are perceived to have below average academic ability in the related curriculum area (Millard, 2009).

Below average chemistry potential students. Below average chemistry potential students are defined as students with an unweighted cumulative GPA of 2.86 or lower on a 4.0 scale at the end of the student's 10th-grade year. This GPA was chosen based on the 3.05 average GPA of the students in the study.

Below proficient rating. Below proficient rating is defined as an indicator of a student's performance level on a particular criterion-referenced assessment based on an established cutscore. A student with a below proficient rating, scores within a range of scores below the lowest cutscore on a multi-level proficiency scale. Students scoring in

this range are below to significantly below average academic ability in the related curriculum area (Millard, 2009).

Beyond proficient rating. Beyond proficient rating is defined as an indicator of a student's performance level on a particular criterion-referenced assessment based on an established cutscore. A student with a beyond proficient rating, scores within a range of scores above the highest cutscore on a multi-level proficiency scale. Students scoring in this range are perceived to have above average academic ability in the related curriculum area (Millard, 2009).

Criterion-referenced test (CRT). Criterion-referenced test is defined as a test which measures a student's performance against a stated criteria or set of learning objectives (Millard, 2009).

Cutscore. Cutscore is defined as the established score at which or above which a student is expected to perform (Millard, 2009).

Differentiated instruction. Differentiated instruction is defined as tailored instructional strategies, content, materials, and/or assessment methodologies to meet all students' learning needs (Differentiating Instruction, 2010).

Essential Learner Outcomes Exams (ELO). Essential Learner Outcomes Exams are defined as criterion-referenced tests given to all students in Millard Public Schools in Omaha, Nebraska. The purpose of these assessments is to determine the level of proficiency that students have achieved with the local curriculum that is aligned with state standards (Millard, 2009).

Extrinsic motivation. Extrinsic motivation is defined as motivation stemming from a wide variety of factors that causes the individual to engage in an activity in order to achieve the external factor (Ratelle et al., 2007).

Global rating. Global rating is defined as the process of predicting current student performance at four levels of proficiency: (a) Beyond Proficient, (b) Proficient, (c) Barely Proficient, and (d) Below Proficient (Millard, 2009).

Graded homework. Graded homework is defined as homework that was assigned by the teacher and allotted points that effected the students overall grade. The homework grade was accessible to both the student and guardian via an internet connection.

Grading for Learning. Grading for Learning is a concept recommending practices to ensure grading for learning including: 1. Relate grading procedures to learning goals. 2. Use criterion-referenced performance standards as reference points to determine grades. 3. Limit the valued attributes included in grades to individual achievement. 4. Sample student performance (do not include all scores in overall grades). 5. Grade in pencil. 6. Crunch numbers carefully if at all. 7. Use quality assessment(s) and properly recorded evidence of achievement. 8. Discuss and involve students in assessment, including grading, throughout the teacher/learning process (O'Connor, 2002).

Intrinsic Motivation. Intrinsic motivation is defined as motivation referring to the doing an activity for itself and the pleasure and satisfaction derived from participation in the activity (Ratelle et al., 2007).

Millard Instructional Model (MIM). The Millard Instructional Model is defined as the five domains: planning, instruction, assessment, learning environment, and professional responsibilities that teachers are to incorporate in order to promote successful student learning. The first four domains within the model are based on the following notions: students succeed because teachers plan with individual learning results in mind, students achieve desired learning results from effective participation in well-designed and executed units and lessons, students are given many opportunities to learn the prescribed curriculum of the Millard Education Program, student develop the capacity to understand and apply knowledge in meaningful ways, student progress is continually monitored and teaching is adjusted to optimize individual learning, students who are not meeting individual learning goals are supported by proactive intervention, student grades reflect evidence of learning, students are engaged in a positive, productive environment established by the teacher, student behavior expectations that comply with Millard policy are clearly taught and effectively implemented, students are expected to meet challenging and differentiated learning goals (Millard, 2008).

Not graded homework. Not graded homework is defined as homework that was assigned by the teacher and allotted points that had no effect on the students overall grade as the points were placed in an exempt category within the grade book. The homework grade was accessible to both the student and guardian via an internet connection.

Proficient rating. Proficient rating is defined as an indicator of a student's performance level on a particular criterion-referenced assessment based on an established cutscore. A student with a proficient rating, scores within a range of scores above the

mid-range cutscore on a multi-level proficiency scale. Students scoring in this range are perceived to have average academic ability in the related curriculum area (Millard, 2009).

Standard scores. Standard scores are defined as scores which can be expressed as raw scores in terms of the mean and standard deviation (Millard, 2009). Teacher prepared 11th-grade assessments matter, atoms, naming, and reactions; district prepared 11th-grade assessment chemistry final, and district graduation requirement physical science strand 11th-grade science ELO assessment were converted to a standard score with a mean of 100 and a standard deviation of 15.

Standard setting. Standard setting is defined as the psychometric process of determining the cutscores that divides a range of scores on an exam into various levels of proficiency. This process includes at least three and usually four simultaneously applied methods to ensure the validity of the cutscores (Millard, 2009).

Significance of the Study

The study contributes to research, practice, and policy. The study is of significant interest to students as they strive for excellence in chemistry education, parents as they try to understand current educational practices and how such practices influence their student, educators and school district officials as they consider implementing grading for learning, including homework grading practices and how these grading practices influence overall course grades and outcomes.

Contribution to research. A review of professional literature suggests that more research is needed on the subject of grading practices as it relates to homework. Furthermore, the results of this study may inform the district central office and building leaders of the impact of homework grading practices on student achievement in the

subject of chemistry. In addition, the findings may indicate specific factors for increasing student academic achievement.

Contribution to practice. A suburban school district may decide whether or not to maintain graded homework practices or switch to ungraded, grading for learning, homework practices in order to ensure students at all academic ability levels learn.

Contribution to policy. The results of this study may offer insight in how grading for learning practices affect student achievement. If results show there is a difference in achievement scores, the school district may choose to reconsider or move forward with the ungraded homework policies attached to the grading for learning paradigm.

Organization of the Study

The literature review relevant to this research study is presented in Chapter 2. This chapter reviews the professional literature related to homework grading practices and academic achievement. Chapter 3 describes the research design, methodology, independent variables, dependent variables, and procedures that will be used to gather and analyze the data of the study. This includes a detailed synthesis of the participants, a comprehensive list of the dependent variables, the dependent measures, and the data analysis used to statistically determine if the null hypothesis is rejected for each research question.

CHAPTER TWO

Review of the Literature

Chemistry has been taught in American high schools for quite some time and yet it is still unclear as to which teaching approach leads to the most success. The current approach involves lecture and laboratory experiences and has been in practice since the early 1840s (Sheppard & Horowitz, 2006). Searching for an effective curriculum and instructional style has perplexed and intrigued high school chemistry teachers and college professors for over a century (Cornog & Stoddard, 1925). Complicating things further, today's schools offer chemistry to most students with basic algebra skills but not necessarily demonstrated conceptual science aptitude requiring teachers to assign often criticized practice based and over learning driven graded homework (O'Connor, 2002).

Historical Importance of Teaching Chemistry to High School Students

From a historical standpoint the importance of chemistry has always been about understanding tomorrow. At the close of World War II, Kinzel (1944) pointed out that an understanding of the world must emphasize some idea of the way atoms and molecules combine to form useful materials and react and that for high school students this process is essential. Looking around the world today helps confirm Kinzel's belief in the importance of basic chemistry. The remarkable chemical advancements over the last fifty years have created a world that was almost unimaginable in 1944 and these advancements continue to be responsible for the important discoveries and technologies that will alter human lives in the 21st-century and beyond (Dingrando, Tallman, Hainen, & Wistrom, 2005). For example, today every aspect of life is impacted by chemical knowledge and discovery including medicine (Wilbraham et al., 2005; Dingrando et al.,

2005; Myers, Oldham, & Tocci, 2004; Carey, 2003, Davis et al., 2002), food (Wilbraham et al., 2005; Myers et al., 2004; Davis et al., 2002), clothing (Wilbraham et al., 2005; Myers et al., 2004; Davis et al., 2002), and energy sources (Wilbraham et al., 2005; Dingrando et al., 2005; Myers et al., 2004; Carey, 2003, Davis et al., 2002) to name a few. All these advancements come at a price leading to the 600 million tons of toxic waste released by factories each year.

Common waste disposal techniques like incineration produce dioxins that are harmful to the environment and human life. The need to safely dispose of waste has led to new chemical waste elimination methods such as ultrasonic waste destruction which is cheaper and cleaner than the current method of incineration (Davis et al., 2002). For too long, business principles have dominated the production of industrial chemicals and with cost always being a factor the cheapest not the safest measures have been implemented. Green chemistry and environmentally benign synthesis are but two methods with which scientists are pushing to find a chemical solution in order to minimize the byproducts causing the current disposal problems (Carey, 2003). Advancements in proper waste handling and destruction continue to be a top priority among scientists in order to allow for the safe discovery and development of life altering goods and processes. All of these chemistry problems, solutions, and innovations are made explicit in the high school chemistry curriculum (Carey, 2003).

Chemical knowledge and discovery in medicine. Some of the greatest chemistry achievements of all time have led to some of the largest advancements in modern medicine (Wilbraham et al., 2005). Over 2000 prescription drugs are in existence today and are used to treat ailments stemming from infections, to high blood

pressure, and depression among other things (Wilbraham et al., 2005; Carey, 2003). Many prescription drugs exist in slightly different formats. According to the Food and Drug Administration (FDA), doctors can currently prescribe over 6000 drugs (FDA, 2010). About 40 percent of these modern medicines begin as a plant or animal chemical, many of which are toxic in their natural form, and then the chemicals are purified and modified by chemists to make them more effective and less toxic in accordance with Food and Drug Administration requirements (Wilbraham et al., 2005). Another reason for chemical alterations to organic medicines is the origin of such chemicals. Some medicines originate naturally but are produced in such minute amounts that synthetic measures are necessary. Other biological medicines originate in specific endangered species of plants and/or animals, so scientists develop methods for duplicating these medicinal chemicals in a lab setting in order to protect the endangered wildlife (Myers et al., 2004).

Synthetic medicines require chemists to alter the chemical building blocks into hundreds or even thousands of variations in order to find the one chemical compound with the right characteristics. The combinatorial chemistry process used to take as long as a week to develop a single synthetic compound and years to discover a chemical with medical uses. Today's advancement in robotics has sped up the process exponentially as chemists now use robots to create hundreds of compounds every day in hopes of finding the right combination (Dingrando et al., 2005). One drug that scientists have been developing and modifying through synthetic measures is a tumor-inhibitory antibiotic characterized by an enediyne structure consisting of a double bond and two triple bonds in a nine to ten member carbon ring. These structures have shown a great ability to

inhibit cancer cell growth but they also have shown a great ability to kill cancer cells more readily than normal cells. These qualities specific to enediyne chemicals may lead to drug development that can cut DNA and stop tumor growth thus aiding in cancer treatment and possible cures for cancer (Carey, 2003).

Students also learn the importance of recent drug modifications involving taking existing complex drugs sold as racemic mixtures with both active and inactive capabilities and purifying them into chiral drugs which are incapable of superimposing into the inactive form. The ability for organic compounds to superimpose has led to complications in pharmaceuticals as the superimposed form may not have the desirable qualities as the original form and may even have life-altering dangerous qualities. Purifying such substances into chiral drugs should lead to more certainty in the drug's qualities as well as fewer unwanted side effects ranging from tiredness to birth defects (Carey, 2003).

Some of the most recent advancements in pharmaceuticals are in the area of nuclear medicine. Nuclear medicines use radioisotopes to diagnose medical problems as well as treat some diseases. These radioisotopes have proven life saving in areas such as thyroid disease and most notably cancer. Radioisotopes have led to new ways of detecting skin cancer as well as less damaging ways to reduce the growth of tumors and safely kill cancer cells (Wilbraham et al., 2005; Davis et al., 2002; Myers et al., 2004).

Medical improvements go beyond the world of pharmacology. Advancements in medical materials have led to better biomedical implants including limbs and joints with robotic abilities to aid in movement and response to motor signals, cochlear implants to aid in restoration of hearing loss, eye implants to assist people suffering from cataracts,

heart valve implants to replace valves damaged by age and disease, as well as the ability to replace skin with a man-made plastic membrane (Wilbraham et al., 2005). Another synthetic solution to medical emergencies is the creation of artificial blood. Currently, perfluorocarbons (PFCs) are used in place of hemoglobin to transport oxygen throughout the body. The creation of PFCs has not led to a truly artificial blood, as PFCs are incapable of clotting and performing immune functions like real blood. However, PFCs have aided in emergency surgical procedures where there is a shortage of real blood, as PFCs can be made readily available with a shelf life of more than a year. Furthermore, PFCs can be used in all patients regardless of blood type which can be life saving when a blood transfusion must be done immediately with no time for blood typing (Wilbraham et al., 2005; Davis et al., 2002).

Further advancements in chemistry have led to the development of the laser and electrosurgical pencil which have led to significant advancements in eye surgery, as well as other surgical procedures such as cauterizing, leading to less invasive procedures (Wilbraham et al., 2005; Dingrando et al., 2005). Less invasive procedures have also become more commonplace due to advancements in x-ray technology. X-rays that at one time could only spot major bone fractures, can now be used to look at small imperfections in the bones. With the assistance of toxic chemical substances like barium sulfate, radiologists are also able to examine organs and other soft tissue areas with the help of x-rays. Ingesting a toxic chemical poses many problems so chemists had to develop the right concentration and mixture with other non-toxic salts in order to prevent the barium sulfate from transferring into the bloodstream (Wilbraham et al., 2005). Beyond x-rays exists magnetic resonance imaging (MRI). Current MRI technology

allows doctors to see the insides of the human body without the harmful effects of x-rays. The MRIs of today show doctors still images of the brain and other biological materials that contain water or fat. The goal for MRIs of tomorrow is to create motion pictures showcasing the inner-workings of the human body; to see the body as it works as opposed to the current capabilities of only examining the structure of a mere organ in order to research bodily function, would have massive implications on future medical discoveries (Carey, 2003).

Possibly the most remarkable advancement in medical science revolves around the Human Genome Project (HGP). HGP involves scientists from around the world working together in a quest to identify the exact location of every gene within a strand of human deoxyribonucleic acid (DNA), resulting in a rough map completed in 2001. Mapping the location of every gene will lead to a better understanding of genetic conditions and mutations which are known to be largely responsible for certain types of cancer and heart disease among other diseases (Dingrando et al., 2005). These types of advancements will end in life-saving results.

Chemical knowledge and discovery in food. Also of tremendous interest for high school students studying chemistry is a concern for how chemical knowledge may be used to address questions of famine and improved food production. The world's population continues to grow while the land available to grow food continues to diminish. This inverse relationship between population and land availability forces scientists to develop new ways to grow more food in less space (Wilbraham et al., 2005). The solution begins with studying crop productivity. In order to increase the amount of crops produced, scientists test the soil and water availability to determine which type of crops

will prosper in the given conditions. If the conditions are right, a known species of plant will be planted in the specific location, if the conditions are not quite right, biochemists can develop hybrids and new species of plants through the use of recombinant DNA techniques in order to produce a plant that is more resistant and will store longer (Wilbraham et al., 2005). This recombinant DNA technique is one way in which plants are able to be grown in less desirable locations but it is also being used to protect the crops until they are ready for harvest.

Beyond genetic alterations of the plants, science has discovered ways to use biochemicals in crop production such as adding the glowing gene of a jellyfish to a few disposable potatoes in order to determine when the whole field needs to be watered and using female pinworm pheromones around a tomato plant to repel other pinworms during mating season in order to reduce pinworm rot are but two ways that chemistry has helped protect plants during the growing season. Other chemicals such as herbicides, pesticides, and fertilizers have been developed by chemists in order to increase the chance of crops surviving until harvest. Many of these chemicals are harmful to humans and animals, so scientists have also developed ways to study the effect of such chemicals through the use of radioisotopes in order to ensure the crops are safe for consumption (Wilbraham et al., 2005; Davis et al., 2002).

Furthermore, science is also working on ways to prolong the shelf life of perishable food items such as produce. In the past, people dried, smoked and salted their foods for preservation. Today, the addition of preservatives, including antioxidants that slow down the oxidation and decay process of foods, antimicrobials that interfere with microbes that spoil food, and nitrogen packing that is similar to antioxidants in that it

blocks oxygen and reduces oxidation, along with refrigeration have allowed food to store longer and thus remain edible for a longer duration (Wilbraham et al., 2005).

Chemical knowledge and discovery in textiles. New materials are always being sought after for clothing, wound dressings, and other assorted fabrics. In terms of the number of scientists and engineers involved, polymer chemistry, leading to fiber development and textile creation, is actually the principle activity of the chemical industry (Carey, 2003). Developing new fabrics with various properties has not happened by chance. In the early 1930s, a decision was made to do basic research in the field of textile development without any guarantees that success would be achieved. The numerous successes in fiber development have far exceeded all expectations (Carey, 2003).

High school chemistry students examine naturally occurring fibers such as silk-- particularly spider silk, a naturally occurring fiber that has been studied for quite some time as it has many desirable qualities such as strength and elasticity. Harvesting silk from a spider is not plausible as a spider will defend its territory, so scientists had to develop a way to produce spider silk without requiring a spider to spin its web. Students learn that scientists were able to identify the silk gene and were able to safely transfer the gene to a goat. As the goat produces milk, the milk contains the silk. By separating the silk from the milk, scientists have been able to create a material suitable for sutures, biodegradable fishing lines, and soft body armor (Wilbraham et al., 2005, Myers et al., 2004).

Both biologically and synthetically generated silk are desirable, but their high price point does not make them useful in many applications, so other materials with

strength and elasticity are necessary. Nylon is one such material that has similar qualities and is thus useful in many types of fabrics. While nylon itself is not a new discovery--invented in 1935 and developed in 1938--the condensation process by which nylon was first synthesized has led to the creation of new materials such as Kevlar and Nomex (Davis et al., 2002; Myers et al., 2004; Carey, 2003). Kevlar is a material widely used in service uniforms as it is as strong as steel and bulletproof. Kevlar is also desirable in service gear as it weighs but one-fifth as much as steel (Davis et al., 2002; Carey, 2003). Nomex is another material made through a very similar condensation process. Whereas Kevlar is used for its strength, Nomex is desired for its fire-resistibility. Nomex has led to new protective gear for firefighters, astronauts, and racecar drivers (Carey, 2003). While condensation polymer materials have proven to lead to better clothing options, the creation of polyester remains the most important textile development to date. More than one and a half million tons of polyester are produced annually in the United States, exceeding the production of cotton at 1.4 million tons and nylon at 1.0 million tons (Carey, 2003).

Besides condensation polymer advancement, other materials are being developed using the phase changing ability of paraffin under relatively cool temperatures. Further studies of paraffin phase changes may lead to cool suits for firefighters and soldiers as well as warm linings in winter attire (Davis et al., 2002). These future textiles are sure to continue changing the way people view clothing and protective gear.

Chemical knowledge and discovery in energy sources. Of significant importance in the study of high school chemistry is understanding the tremendous amounts of energy needed to meet the needs and wants of modern society. Heating

buildings, manufacturing and processing goods, and transporting goods and people, all require energy. In the high school chemistry curriculum students are challenged to move beyond their own communities and understand the relationship between increased industrialization, population, and energy demands and the vital role chemistry will play in finding ways to conserve, produce, and store energy (Wilbraham et al., 2005).

Conserving energy is aided through the use of insulators such as Styrofoam coffee cups and foam insulation in homes (Wilbraham et al., 2005). Students are also confronted with the immediacy of developing new forms of energy as the current supply of carbon based fossil fuels--a finite resource--will soon be outstripped by demand. Students are introduced to plant fuel alternatives such as biodiesel and ethanol (Wilbraham et al., 2005).

Solar energy alternatives are also explored in high school chemistry. Large quantities of energy can be produced by a solar power plant as the earth receives about 200,000 times the total world electrical generating capacity every day. Harvesting solar energy can be costly and require a large amount of space. Advancements in science have led to the creation of concentrating solar power (CSP) technology. CSP technology uses a field of mirrors known as heliostats to concentrate the sunlight on a receiver at the top of a tower. While CSP technology still requires a large amount of space, it is much less expensive than using water or molten salt receivers as had previously been used (Wilbraham et al., 2005). Passive forms of solar energy also exist and are accessible by nearly everyone. Passive solar energy is based on building components such as triple-pane windows, heavily insulated walls, and other building materials that are high in energy storage such as adobe and clay tile. Simply by choosing the right building

components, solar energy is put to use and thus the need for fossil fuels is reduced (Dingrando et al., 2005).

Another form of energy that is currently under scrutiny and found to be controversial by many high school students is nuclear energy. Nuclear energy is produced through a chain reaction known as fission in which the nucleus splits into smaller fragments releasing large amounts of energy. Fission reactions release so much energy so quickly that they can be hard to control and can lead to devastating amounts of energy released as was seen in World War II atomic bombs and the Chernobyl nuclear power plant tragedy. Modern science has developed new reactors to help control both neutron moderation and neutron absorption, the processes necessary in capturing the release of nuclear energy in a fission reaction, in order to reduce the risk of a reactor meltdown, hence reducing the risk of a life-threatening release of excess radiation. Current studies continue to surround the controversy of nuclear waste and discovering ways to properly dispose of the spent radioactive fuel rods, as the rods may remain dangerously radioactive for thousands of years. A likely alternative is fusion energy that combines nuclei rather than splitting them. While it produces much less radioactive waste than fission, it is harder to control the energy and requires extremely high temperatures to initiate such a reaction. Scientists continue to evaluate fusion energy but at the current time have not discovered sufficient ways to harness it for public use (Wilbraham et al., 2005; Davis et al., 2002; Dingrando et al., 2005, Myers et al., 2004).

Another major source of potential energy remains in methane sources found deep under the ocean floor. As the methane seeps out, the gas becomes trapped inside water molecules forming methane clathrates. The amount of methane clathrate at the bottom of

the ocean contains more potential energy than all the known oil reserves on earth.

Currently the ability to harness such energy is a mere curiosity as the extraction process is not economical at the present time. Studying potential energy sources hidden by the vast oceans continues to intrigue scientists as they search for new and better ways to tap into what may become vital energy sources (Carey, 2003).

The National Aeronautics and Space Administration (NASA) has developed the Flameless Ration Heater (FRH) that works through a series of chemical reactions. In simplified terms, FRH works by harnessing the energy that is released during the corrosion of a metal. The vigorous corrosion reaction that NASA developed allows food to be heated up in just a few minutes allowing military personnel and astronauts to have quick access to hot meals (Wilbraham et al., 2005). The HeaterMeals Company, one company responsible for making FRH packaging, manufactured approximately 80 million heaters for the United States military during the 1990s and is currently marketing the heating source to long-distance truck drivers (Davis et al., 2002).

Storing energy is another area of concern and has recently been aided in NASA's development of rechargeable batteries for use in such items as power tools, cell phones, and lap top computers. A more impressive use for rechargeable batteries exists in the development of lithium-ion rechargeable batteries that perform at low temperatures, for use in space exploration (Surampudi, Smart, Huang, & Ratnakumar, 1997). An even more impressive energy source exists in the form of a fuel cell. Like batteries, fuel cells produce electricity through redox reactions. Unlike batteries, a fuel cell is able to generate an indefinite electric current as it uses an outside fuel source such as hydrogen to keep the reaction going. Fuel cells are a viable energy alternative as NASA has

already used them to provide space crews with electrical energy. However, for fuel cells to be a plausible energy source for regular consumption, scientists must develop a method for suitable hydrogen production (Dingrando et al., 2005; Myers et al., 2004). Energy advancements continue to be a major focus for NASA and other chemists. As the amount of fossil fuel available decreases, our need for new energy sources increases, and scientists are working diligently to come up with viable energy solutions.

The National Chemistry High School Curriculum

Currently, the most obvious reason to teach chemistry to high school students is so they are prepared to master chemistry coursework in college--a requirement for all pre-medical, pre-pharmacy, and pre-nursing students. Because of the importance of chemistry knowledge it has been long held that teaching chemistry topics should begin as early as elementary school (Berry, 1986). Furthermore, it has been asserted that the fundamentals of chemistry aid in the success of students ability to work with others, learn independently, solve problems, and think critically both scientifically and mathematically (Lastica, 2009; Englerth, 2006). High school chemistry courses assist students in developing ways to study and organize more difficult concepts that may be useful in future endeavours (Englerth, 2006). Moreover, teaching students to read, write, and discuss coherently about science is essential to scientific literacy and conscientious citizenship (Walczak & Walczak, 2009). With media playing such an important role in the lives of our youth, it is important that they can think critically and conscientiously about science issues they see in commercials, in the newspaper, on the news, and in other various media outlets (Lastica, 2009).

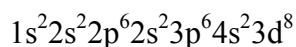
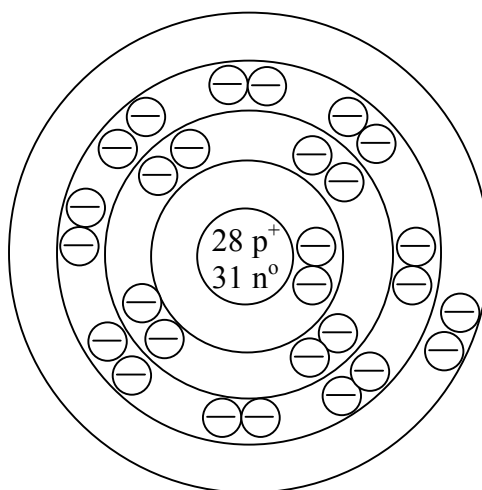
Contemporary high school chemistry curriculum standards are based on national science education standards. The first set of national standards was established by the National Council of Teachers of Mathematics in 1989 and by 1992, a national set of standards were recommended for all subject areas including chemistry. With the introduction of *No Child Left Behind* (2002), national standards for chemistry were required (Barton, 2009).

Within the national K-12 science standards lies a subsection on physical science. Chemistry falls under the physical science umbrella where the national standards for chemistry can be found (National Committee on Science Education Standards and Assessment & National Research Council, 1996). The major high school chemistry topics include (a) structure of atoms, (b) structure and properties of matter, (c) chemical reactions, (d) conservation of energy and the increase in disorder, and (e) interactions of energy and matter (National Committee on Science Education Standards and Assessment & National Research Council, 1996). Each of these overarching chemistry topics has many smaller fundamental concepts and principles that define the high school chemistry curriculum.

Structure of atoms. The structure of the atom is composed of subatomic particles, each with a specific function and location. Understanding the structure of an atom involves studying its history filled with numerous scientists and various discoveries, all of which has led to the current cloud concept of the model involving quantum mechanics and the uncertainty principle. The location and function of the proton and neutron are pretty easily explained; both are found in the nucleus and the proton is responsible for the atomic number and identity of the atom while the neutron contributes

to its mass and different isotopes. Learning about the electron is more difficult as its location is based on a series of overlapping and different shaped atomic orbitals giving the electron a probable location based on the atom's electron configuration.

Furthermore the number of electrons in the outermost ring is responsible for the reactivity and bonding capabilities of the atom. These outer electrons known as valence electrons are able to transfer between atoms creating ions and ionic compounds such as salt. They are even sometimes shared between two atoms in order to create molecules such as water (Wilbraham et al., 2005; Zumdahl, Zumdahl, & DeCoste, 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002). Orbital notation and electron configurations are an essential component of high school chemistry coursework. The orbital notation and electron configuration for the element nickel are:



The theory that electrons must exist in an orbital aids in understanding electromagnetic energy and has led to the discovery of atomic emission spectra which can be used to identify elements in celestial bodies as well as substances found here on earth. Electromagnetic energy moves in a wave pattern and by measuring the wavelength of the

wave, the energy can be classified as radio waves, light waves, or even gamma waves.

The frequency with which the wave cycles can be calculated by using the wavelength and the speed of light as all electromagnetic energy travels at the same speed. The high school standards require that students express the chemical relationship using the formula $c = \lambda\nu$. This calculation would be utilized in the following example:

What is the frequency of a wave with a wavelength of 2.3×10^{-12} m?

$$c = 2.998 \times 10^8 \text{ m/s} \quad \nu = 2.3 \times 10^{-12} \text{ m}$$

$$2.998 \times 10^8 \text{ m/s} = (\lambda)(2.3 \times 10^{-12} \text{ m})$$

$$\lambda = 1.30 \times 10^{20} \text{ Hz}$$

The frequency is used to classify the energy as safe or dangerous and visible light exists right in the middle of the pack. Electromagnetic energy with high frequency such as 1.30×10^{20} Hz emits radiation and may cause harm to humans and other living species. At the far end with the highest frequency is where gamma radiation is found. Of all the nuclear radiations, gamma radiation is the most dangerous (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002).

When a nuclear reaction occurs, whether it's an alpha or beta decay, or proton or neutron emission, gamma radiation is usually given off throughout the course of the reaction. Nuclear reactions help to explain how nuclear energy can be harnessed as well as how nuclear radiation can cause free radicals in a person leading to certain forms of cancer. Nuclear chemistry is also used by scientists and archeologists to carbon date artifacts and remains through calculations known as half-life reactions (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002).

The process for calculating half-life is:

1. Calculate the ratio of mass remaining to original mass to determine the number of half-lives the substance has undergone.
2. Calculate the length of one half-life by dividing the elapsed time by two for as many half-lives as the substance has undergone.

Understanding the atom also involves understanding kinetic theory that explains atoms are always in constant motion and have perfectly elastic collisions. Kinetic theory is behind the explanation to why the atoms in a gas behave as characteristically described in the gas laws. Gas laws involve algebraic calculations used to predict how the volume, pressure and/or temperature of the gas will react to changes in one of the other variables. These laws explain why the volume of a balloon expands and contracts with temperature changes, or why the pressure in car tires fluctuates with the changing weather (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002) and are expressed using the following calculations:

$$\text{Boyle's law: } P_1V_1=P_2V_2$$

$$\text{Charles' law: } \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\text{Gay-Lussac's law: } \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\text{combined gas law: } \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\text{ideal gas law: } PV=nRT$$

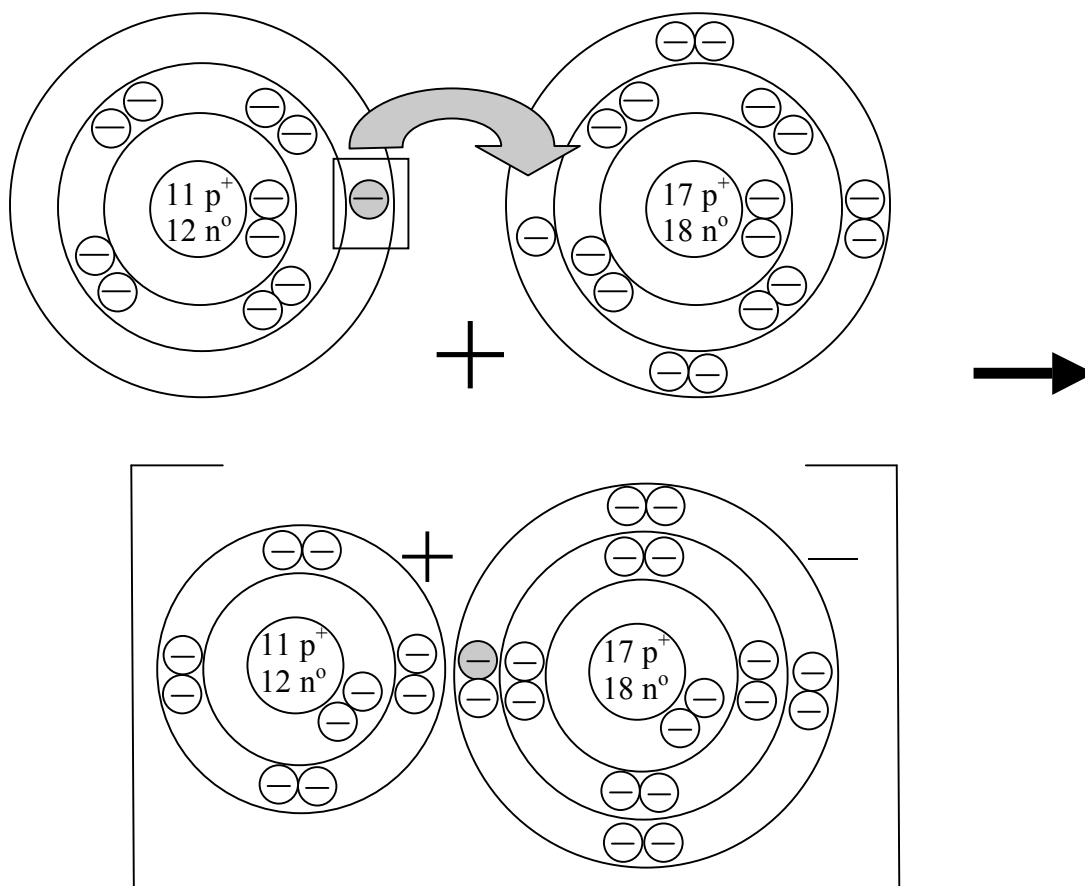
$$\text{Dalton's law: } P_t = P_1+P_2+P_3\dots$$

$$\text{Graham's law: } \frac{\text{rate}_A}{\text{rate}_B} = \sqrt{\frac{\text{molar mass}_B}{\text{molar mass}_A}}$$

Structure and properties of matter. Matter is classified as an element, compound, homogeneous mixture, or heterogeneous mixture. Each of these different substances can be identified through unique physical properties such as color, density, or boiling point. The freezing point and boiling point of a substance helps to create a phase change diagram as well as a heating curve. Chemical properties such as flammability and reactivity can also be used to identify a substance. Discovering these types of properties of known elements aided in the creation of the current periodic table (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002).

The periodic table is used to organize the existing elements as well as predict the properties of unknown elements. It is strategically arranged according to periodic law that is based on the octet rule or number of valence electrons in any given element. The number of valence electrons determines how reactive or inactive an element will be and is the basis for the groups or families on the periodic table. The location of an element on the periodic table is used to determine which elements will bond with other elements and in what ratio they will come together. By drawing Lewis dot structures a person can begin to understand how an electron can leave a metallic atom and become a positively charged cation. In the same respect a nonmetallic atom will receive the donated electron and become a negatively charged anion. The difference in these charges creates a magnetic force pulling the two ions together and thus creating an ionic compound. Understanding how cations and anions are formed in order to create an ionic bond is important to understanding ionic compounds.

For example the basic ionic structure for table salt (NaCl) is displayed with the following ionic structure:



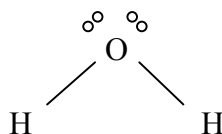
Nonmetals are capable of bonding with other nonmetals but due to the fact that they are both electronegative, with a desire to attract electrons, donating and accepting electrons will not occur. Instead, the two nonmetals are held together in a tug of war over one or more electrons, resulting in compounds with very different characteristics than ionic compounds. In fact seven of the nonmetals are so reactive that they only exist bonded to another atom of its type in a diatomic molecule-- H_2 , O_2 , F_2 , Br_2 , I_2 , N_2 , Cl_2 . Molecular bonding results in molecules with specific geometries according to the number of valence electrons in the central atom. Students learn how nonmetals share electrons, according to Valence Shell Electron Pair Repulsion (VSEPR) theory, to create linear,

bent, trigonal planar, trigonal pyramidal, and tetrahedral molecules. VSEPR theory is also one way to determine if a molecule is polar or nonpolar. Students are also expected to distinguish between polar and nonpolar molecules in accordance to these geometries.

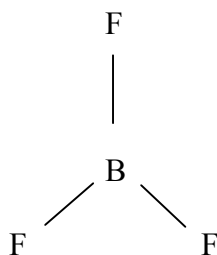
Diatomic molecules are always linear as seen in this hydrogen molecule:



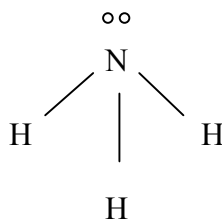
Water molecules are bent:



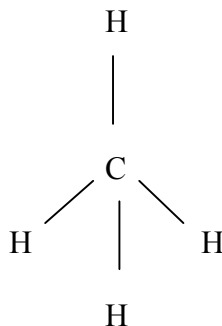
Boron trifluoride, used in semiconductor manufacturing, is trigonal planar:



The ammonia molecule is trigonal pyramidal:



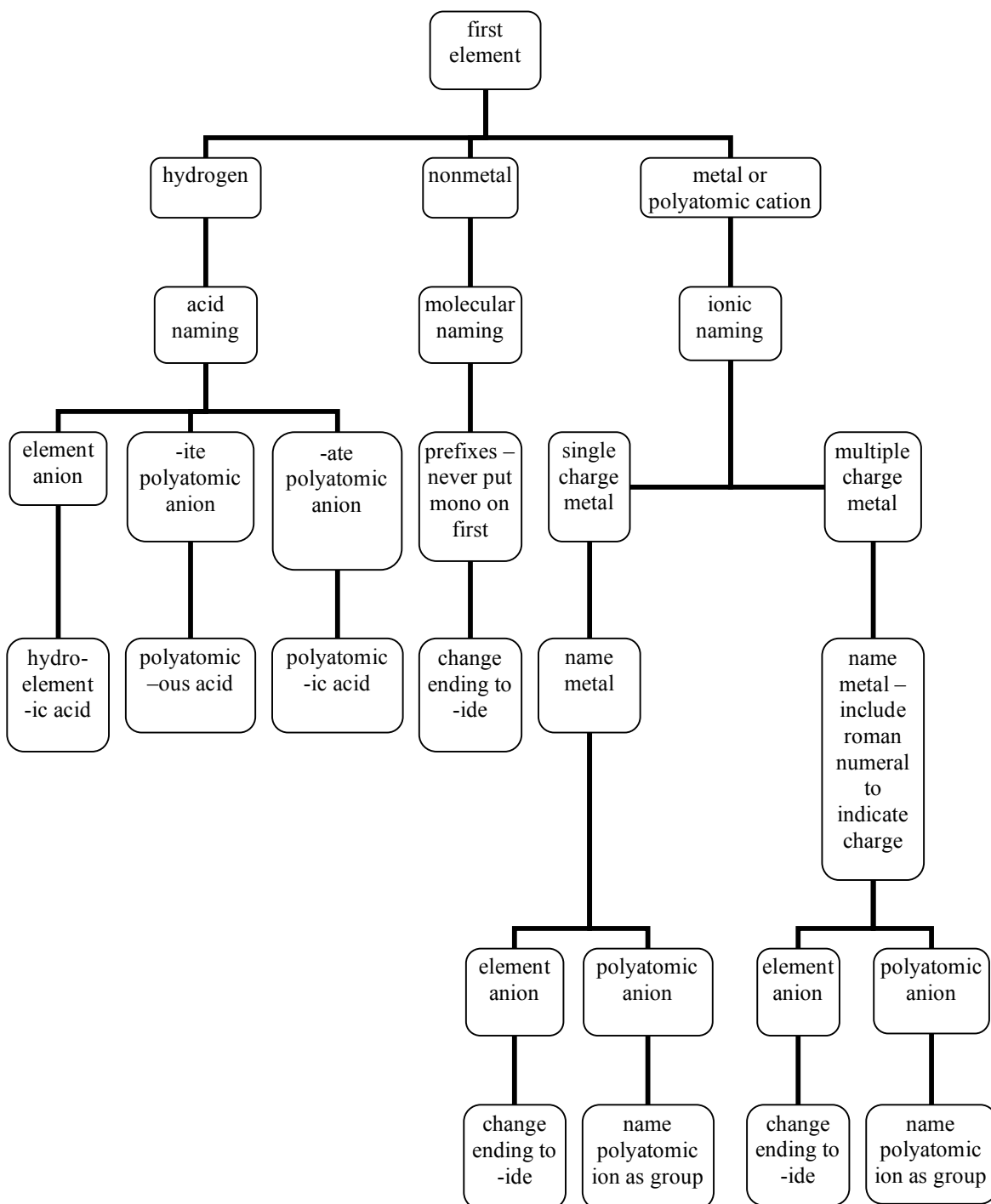
A methane molecule is tetrahedral:



Polar molecules are asymmetrical and will have a slight charge, whereas, nonpolar molecules are symmetrical and will have no charge. Students learn that polar molecules will only dissolve other charged compounds such as ionic compounds and other polar molecules but they are incapable of dissolving uncharged compounds such as nonpolar molecules. For this reason water will dissolve table salt and ammonia but it will not dissolve methane (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002).

Ionic and molecular compounds vary in both properties and nomenclature. The nomenclature of ionic compounds is split into three main categories: single charge cation naming, multiple charges cation naming, and acid naming. Ionic naming also involves naming and using polyatomic ions within each of the three categories. Molecular nomenclature has two main categories: molecular naming and organic naming.

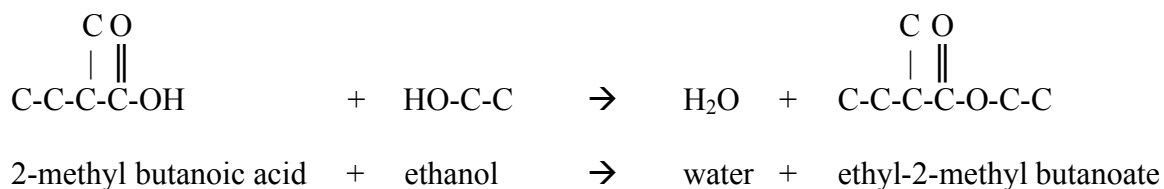
The students are taught how to name inorganic compounds according to the following flowchart:



Organic naming is split into various other categories as organic chemistry is classified separate from inorganic chemistry. High school chemistry students learn how to name nine of the many categories within organic chemistry according to the following chart:

Functional Group	Structural Formula	Naming Suffix
Alkanes	-C-C-	-ane
Alkenes	-C=C-	-ene (indicate location)
Alkynes	-C≡C-	-yne (indicate location)
Alcohols	-C-OH	-ol (indicate location)
Ethers	-C-O-C	ether (alphabetical)
Aldehydes	$\begin{array}{c} \text{O} \\ \\ -\text{C} \end{array}$	-al
Ketones	$\begin{array}{c} \text{O} \\ \\ -\text{C}- \end{array}$	-one (indicate location)
Carboxylic Acids	$\begin{array}{c} \text{O} \\ \\ -\text{C}-\text{OH} \end{array}$	-oic acid
Esters	$\begin{array}{c} \text{O} \\ \\ -\text{C}-\text{O}-\text{C}- \end{array}$	-oate (side chain followed by parent chain)

More naming rules exist beyond the identification and suffix chart. The students need to memorize prefixes, rules for finding the parent chain, and rules for naming the branches in addition to the rules for naming the parent chain. The students are also expected to understand organic synthesis reaction such as the dehydration reaction involved in esterification. The following reaction is the esterification of ethyl-2-methyl butanoate:



Regardless of the type of naming involved, the flipside to naming a compound is writing the formula for the compound. Formula writing is essential as it serves as the shorthand form of the name, but more importantly it gives scientists a quick visual representation of the makeup of the compound (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002).

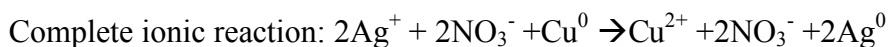
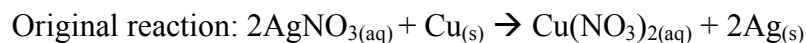
Compounds are used to create homogeneous and heterogeneous mixtures. Mixtures can exist as solutions, colloids, and suspensions. Solutions are homogeneous mixtures and thus are made to specified concentrations measured in molarity, molality, and percent solution. In science these solutions may be used in experimentation; in life, they show up on the grocery store shelf as vinegar and hydrogen peroxide, among thousands of other solutions. Colloids are a heterogeneous mixture but look homogeneous like a solution, so the Tyndall effect is used to identify a substance as a colloid. Common colloids are whipped cream and gelatin. Suspensions are also heterogeneous mixtures but they are easier to identify than a colloid, as the particles in a suspension are large enough to settle out like Italian salad dressing (Wilbraham et al., 2005; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002). High school chemistry students also learn about more complicated colloids. Emulsions are colloids involving two immiscible liquids. By using an emulsifying agent small particles of oil are able to remain suspended in water creating foods such as milk, margarine, and

mayonnaise (McClements, 2005). These food chemistry examples are often used in class to demonstrate homogeneous and heterogeneous mixtures.

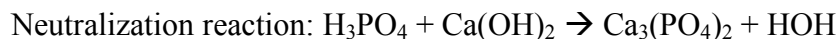
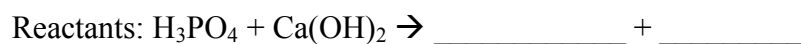
While some types of matter exist as a pure substance and others exist as a mixture, interaction between various types of matter is always occurring. Specific interactions between substances are called chemical reactions.

Chemical reactions. Chemical reactions always result in chemical changes that are classified by color change, gas formation, precipitate formation, or energy transfer. During any type of reaction matter is conserved according to the law of conservation so substances react in very specific ratios with one another that can be shown through a balanced chemical equation. The law of conservation along with metal reactivity and solubility rules allow for scientists to predict the products of a reaction and write a chemical equation explaining such a reaction. Scientists have discovered ways to speed up reactions with the addition of a catalyst (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002).

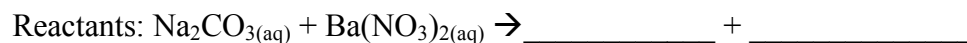
Chemical reactions exist in one of two categories; redox reactions and non-redox reactions. Redox reactions involve electron transfer and may be more specifically classified as either combustion, synthesis, decomposition, or single replacement reactions, based on the reactants and products involved. Redox reactions are broken down into half-reactions known as oxidation and reduction reactions. High school chemistry students are expected to understand a redox reaction and split it into the component oxidation and reduction half-reactions. The following is an example of a single-replacement redox reaction including the break down into half-reactions for silver nitrate (AgNO_3) and copper (Cu):



Non-redox reactions include acid-base reactions and double-replacement reactions. Neutralization reactions are used in acid/base chemistry. A neutralization reaction involves a strong acid and a strong base combining to create a salt and water. High school chemistry students need to be able to predict the products of a neutralization reaction like the following reaction between phosphoric acid and sodium hydroxide:

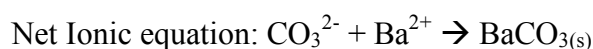
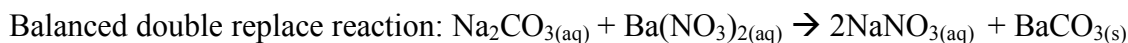
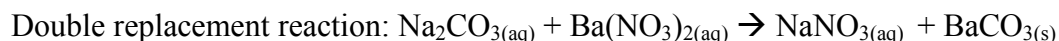


Double replacement reactions are used in solution chemistry and are broken down into net-ionic reactions. Net-ionic reactions are used in order to separate the spectator ions from the ions involved in the creation of the precipitate (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002). Through the use of solubility rules, students can predict which product is the precipitate and can write the net ionic reaction like the following reaction between sodium carbonate (Na_2CO_3) and barium nitrate ($\text{Ba}(\text{NO}_3)_2$):



Na and Ba switch places to form products: $\text{NaNO}_3 + \text{BaCO}_3$

Determine which product is a precipitate based on solubility rules: NO_3^- compounds are soluble; CO_3^{2-} compounds are insoluble so NaNO_3 is aqueous and BaCO_3 is solid.



Conservation of energy and the increase in disorder. The law of conservation of energy states that energy cannot be created nor destroyed. There is a finite amount of energy on earth and in order for one substance to take in energy, something else must release energy. The idea that energy is conserved has led to new studies in different forms of energy such as the use of fuel cells and nuclear energy. Studying energy also entails studying batteries, more specifically electrochemical and voltaic cells.

Electrochemical cells can be used to convert chemical energy into electrical energy through a non-spontaneous redox reaction. Voltaic cells are able to produce energy by a spontaneous redox reaction and have led to the creation of dry cells, lead storage batteries, and fuel cells for contemporary green power automobiles (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002).

Interactions of energy and matter. Much of what high school chemistry students study about energy is intertwined in the teaching of matter and chemical reactions. In any case, chemical reactions always involve energy transfer as bonds must

be broken and reformed in order for a chemical reaction to occur. When bonds break, energy is released and when bonds form, energy is required. This energy transfer causes some reactions to be exothermic while others are endothermic, but in the end it all balances out due to the law of conservation of energy. By understanding the basics of heat transfer within a reaction, students are introduced to thermochemistry (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002). In high school chemistry, students learn how to calculate the heat of a reaction using the following formula: $q=mc\Delta T$.

Understanding gas laws has led scientists to believe that temperature and kinetic energy are related. As temperature increases, atoms move faster and as temperature decreases atoms move slower. This concept has led to the belief that matter will change and possibly not even exist at absolute zero; approximately -273°C (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002).

Nebraska Science Standards

On May 8th, 1998, the Nebraska State Board of Education adopted the state science standards. Nebraska Department of Education science consultants developed thirty-three standards that the students should master between 9th and 12th grade. The thirty-three standards are organized into eight themes. Some of the standards are all encompassing, pertaining to all science classes while others are more specifically designed to fit into a certain subject area. The general standards include students developing an understanding of systems, order and organization; evidence, models, and explanation; change, constancy and measurement; form and function; and change over

time (Nebraska Department of Education, 1998). Another general standard states that students will develop the abilities needed to do scientific inquiry that entails lab procedures and measurements (Nebraska Department of Education, 1998). The final general standards involve critical thinking in the areas of science and technology, science in personal and social perspectives, and history and nature of science (Nebraska Department of Education, 1998).

Critical thinking. While understanding concepts is one of the key focuses in education, a higher level of thinking must be applied when studying science. In order to actively learn and understand science, a person must be able to think critically. Critical thinking involves re-constructing experiments, creating and conducting new experiments through inquiry and the scientific method, collecting and interpreting data, and generating and understanding graphs. Furthermore, critical thinking involves collaboration and communication. Scientific discoveries are usually made through years of team effort and impeccable communication in the lab and around the globe (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002).

Inquiry and measurement. In order to conduct any experiment or perform any scientific calculation, the basics of measuring must be understood. In general, scientists measure using the International System of Units (SI units) as science is a world language. Understanding the SI system first involves knowing which base units belong with which measurements, such as length is in meters, temperature is in Kelvin, and amount of a substance is in moles. Beyond the base units, metric prefixes must be understood as many times the base unit does not match up to the unit on the instruments used in scientific investigations. For example, while the base unit for length is meters, most

length measurements are made in either centimeters, nanometers, or picometers.

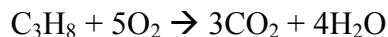
Understanding prefixes allows a scientist to make the necessary measurements and then convert the measurements into the required unit in order to perform the requisite calculations (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002).

Scientists strive for accuracy and precision in their studies. In order to achieve accuracy an experiment will be repeated numerous times using significant figures in all the measurements. In order to test precision, scientists will compare a found result with a previously published result throughout the process. All along the way, the scientists calculate uncertainty based on the instruments used. In the end, error can be calculated to determine if the experiment or reaction was successful or not. These steps are vital as many reactions are conducted in order to produce foods and medications that humans and animals consume (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002).

Arguably the most important calculation a chemist will perform is stoichiometry. Stoichiometry is used to determine how much of a substance will be produced from given quantities of reactants. Using the right amount of reactants allows scientists to reduce costs and waste as they can limit the amount of excess reagent remaining once the limiting reagent is used up. Stoichiometric calculations involve understanding many different components within chemistry--from formula writing, to balanced equations, to unit conversions, to correct measurements (Wilbraham et al., 2005; Zumdahl et al., 2002; Dingrando et al., 2005; Myers et al., 2004; Davis et al., 2002).

Stoichiometric calculations are part of the required high school chemistry curriculum. The students learn how to calculate the amount of a substance given the amount of another substance and a chemical reaction.

The students must be able to convert between mass, volume, and number of particles as seen in the following examples:



Calculate the volume of carbon dioxide (CO_2) produced by 23 grams of propane (C_3H_8) at standard temperature and pressure using the periodic table and/or mole conversions.

$$\frac{23 \text{ g C}_3\text{H}_8}{44.11 \text{ g C}_3\text{H}_8} \times \frac{1 \text{ mol C}_3\text{H}_8}{1 \text{ mol C}_3\text{H}_8} \times \frac{3 \text{ mol CO}_2}{1 \text{ mol C}_3\text{H}_8} \times \frac{22.4 \text{ L CO}_2}{1 \text{ mol CO}_2} = 35.04 \text{ L CO}_2$$

Calculate the mass of water (H_2O) produced from 4.5×10^{21} oxygen (O_2) molecules using the periodic table and/or mole conversions.

$$\frac{4.5 \times 10^{21} \text{ O}_2 \text{ molecules}}{6.02 \times 10^{23} \text{ O}_2 \text{ molecules}} \times \frac{1 \text{ mol O}_2}{1 \text{ mol O}_2} \times \frac{4 \text{ mol H}_2\text{O}}{5 \text{ mol O}_2} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 0.108 \text{ g H}_2\text{O}$$

Topics to Study in High School Chemistry

Chemistry is such a vast science that it is impossible to teach everything in just one year. For that reason, it has long been debated what should be taught at the high school level. A study in 1981, surveyed chemistry teachers from over 140 schools and found that 80 percent of the teachers surveyed only agreed on 44 percent of the fifty chemistry topics listed in the study (Walker, 1982). Most agree that enough information must be covered that the students have enough of an understanding of chemistry that they can appreciate scientific advancements regardless of whether they are future science majors or not (Walker, 1982). According to the high school subcommittee of the American Chemical Society, a general appreciation in the field of chemistry may include

atomic theory, the periodic table, bonding, stoichiometry, states of matter, solutions, chemical reactions, descriptive chemistry, biochemistry, and other special topics (American Chemical Society, 2010). Another institute stated that basic chemistry skills include the metric system, precision and accuracy, scientific notation, significant figures, dimensional analysis, measurement, matter, solubility, and energy (Kreiser, 1981). The two lists are quite different.

Yet, there is still another list. This list includes topics of study that are important to future science majors. This list includes balancing equations, nomenclature, stoichiometry, gas laws, solutions, the periodic table, atomic structure, and problem solving (Streitberger, 1985). While this list is great for future science majors, Streitberger does point out that high school teachers have an additional problem when planning what to teach each day because not all the students are future science majors (Streitberger, 1985). A group of California professors tried to tackle the high school curriculum and their list included such things as algebra, proportions, exponents, significant figures, dimensional analysis, nomenclature, percent composition, balancing equations, gas laws, the mole concept, and atomic theory. The group also went on to say that the high school content for non-science majors should be different than the content for prospective science majors (Berry, 1986).

Another poll was taken about 20 years later, this time high school teachers were asked what they are currently teaching at the high school. At least 75% of the 571 teachers surveyed reported teaching the following topics: balancing reactions, naming and formula writing, moles, basic skills such as units, significant figures, and graphing, atomic structure, periodic table, matter, energy, stoichiometry, bonding, dimensional

analysis, types of reactions, basic lab skills, solutions, gas laws, data analysis, atomic theory, and Lewis dot structures (Deters, 2006). The extensive list helps explain the difficulty behind learning high school chemistry.

Chemistry as a Historically Difficult Subject

Chemistry is usually labeled a *hard* class and is conceptually daunting (Harrison & Treagust, 2001). Many students find science challenging and confusing especially in the area of abstract reasoning which is so prominent in chemistry because almost every concept must be explained through the use of models (Harrison & Treagust, 2001). Over the years, high school chemistry teachers have tried to simplify the difficult concepts involved in understanding chemistry. Unfortunately, by trying to make the concept *easier* the students have begun to focus on getting the right answer rather than trying to understand the conceptual problem solving so pertinent in learning this high-level hard science (Hand, Eun-Mi Yang, & Bruxvoort, 2007). The difficulty level of chemistry can also be seen when looking at the knowledge level of post-high-school chemistry students. One study found that students were able to handle the algebra involved in chemistry but they had difficulty answering questions pertaining to units, variables, plug-in problems, and conceptual problems (Robins, Villagomez, Dockter, Christopher, Ortiz, Passmore, & Smith, 2009). Many students graduate high school with the ability to successfully compute a calculation with little ability to explain conceptually what the calculation means (Hand et al., 2007). Simplifying chemistry may be one reason the students are learning less. Chemistry is an exact science and requires that the teacher inspire students to have high expectations for themselves in order for the students to produce quality work (Perimutter, 1978).

Chemistry is known as the central science and is the basis to scientifically understanding everything in this world from food to plastic and everything in between (Metz, 2009). The topic is so vast and so abstract, yet so important, that Dudley Herschbach, winner of the 1986 Nobel Prize in Chemistry, stated that teaching general chemistry was his most challenging assignment (Metz, 2009). Understanding chemistry is different than understanding many other high school concepts and may take more practice than non-science courses.

To complicate chemistry further, chemistry is no longer a class designed for future chemistry majors. In the late forties, early fifties high schools began offering integrated science courses for the non-science majors. Chemistry teachers only taught students that were competent and interested in chemistry (Weaver & Webb, 1951). That trend has since relinquished in many school districts and now many chemistry classes are an integrated mix of students who desire to be chemistry or medical majors and those that desire to be non-chemistry majors. Making chemistry interesting to a non-science major is challenging. Whether the student is interested in chemistry or not, they have to be engaged in order to be successful (Walczak & Walczak, 2009). Part of this engagement requires daily homework completion in order to learn the difficult concepts (Perimutter, 1978).

Importance of Study Skills and Work Habits in College Chemistry

It should be understandable that practice, possibly extensive practice, is required to master a difficult concept such as chemistry. The more difficult the material or concept the greater the amount of practice or homework there will be (Perimutter, 1978). As early as the 1930s, some colleges realized that even those students that took high

school chemistry were not ready for the course load of college chemistry. Thus leveling the general chemistry classes at the college level came about. Students were placed in elementary chemistry when they were not capable of doing the work in scientific chemistry (Clark, 1938). Other colleges offered a pre-course designed to introduce basic concepts and enhance the students' work habits prior to being placed in college chemistry. In order to improve work habits and time management, large amounts of homework were assigned (Kreiser, 1981).

High school teachers must prepare their students for what to expect at the college level in order for him/her to be successful. Part of that preparation is emphasizing good, personal study habits that come in the form of note taking and homework completion (Streitberger, 1985). Students partaking in more rigorous, honors level high school chemistry classes perform better at the college level because the transition into the complex and difficult course of college chemistry is easier for him/her to make. It is believed that successful transition is a function of higher expectations and not simply exposure to a more difficult subject matter (Lamb, 1991).

Numerous studies have been done with regard to success in college level general chemistry and many acknowledge that motivation and study skills play a large role in determining student performance (Hahn & Polik, 2004). While it is difficult to truly quantify motivation and study skills, homework scores can be used as an indicator of the student's study skills. It is believed that students that complete weekly homework have better study skills than their counterparts that do not complete weekly homework (Hahn & Polik, 2004). Homework scores can also help indicate the student's motivation to be successful in the class. In one study, homework scores were strongly correlated to the

student's outcome in the chemistry course. The study showed that if a student is motivated to do well on the homework, he/she is motivated to do well in the class (Hahn & Polik, 2004).

In another college level chemistry study, high correlation between homework and midterm exams as well as overall course achievement were found, suggesting that homework plays an important role in the success of the students (Cuadros, Yaron, & Leinhardt, 2007). Knowing what it takes to be successful at the college level helps guide what needs to be happening at the high school level. In a world where high schools are designed as college preparatory institutes, it is important they we prepare students for what may become their future (Barton, 2009). Students in high school chemistry are bound to become frustrated and overwhelmed by the course material and amount of work involved in mastering such material. The aforementioned studies, clearly assert that high school chemistry teachers must continue to challenge their students to overcome frustration and tough workloads in preparation for future college science coursework.

Amount of Homework

In the late 1800's to early 1900's it was believed that academics were to take place at school and homework was to be minimal. It was even taken so far as to state that the physical and mental health of pre-teens was threatened by drill, memorization, and recitation. Laws were established regarding the amount of homework that could be assigned (Gill & Schlossman, 2004). Studies, even into the 1930's were critical of homework, even threatening ill effects to students. One such study concluded, "...that homework in the pre-high school grades had no beneficial effect on school achievement"

(Gill & Schlossman, 2004, p. 176). With such laws and studies in place, homework took a backseat to a student's largely rural farm and family life of the time.

Homework remained an education option until the Soviet Union launched the first satellite to orbit the earth called *Sputnik* in 1957. Scientific researchers and practitioners were shocked into the realization that the United States of America had fallen terribly behind in the basic and applied sciences and were forced to go back to the drawing board and refocus on the necessity of homework and rigor in the science classroom. Education and lack of homework was being blamed for America's failures in scientific, military, and economic knowledge advancement. Education and the advancement of scientific knowledge, maybe the first time, in our nation's history was taken seriously because it had become an instrument of the national defense policy (Gill & Schlossman, 2004). Science coursework in the late 1950's and early 1960's required a seriousness of purpose and necessitated homework--a reversal from an earlier time (Gill & Schlossman, 2004).

In the 1980's, as economic competition from around the world became more evident, the government published, *A Nation at Risk* (National Commission on Excellence in Education, 1983), again calling for more homework as an answer to global competition, laying down ground rules for how educators should educate to meet this challenge (Gill & Schlossman, 2004). Remarkably, while the government pushed for an increase in homework, few students reported actually doing more homework--even when assigned (Gill & Schlossman, 2004).

The turn of the century brought more government interventions. *No Child Left Behind* (2002) was the latest attempt to overhaul the current educational system. Standards based education once again brought the homework debate into the limelight.

From *USA Today* to Oprah, homework was being discussed. Most media attention was focused on the excessive amounts of homework being assigned to our nation's high school students (Gill & Schlossman, 2003). Interestingly enough, students still did not report doing more homework. One report found that the percentage of high school seniors doing less than an hour of homework a week doubled from 8.5% to 15.9% between 1988 and 2003 (Schroeder, 2003).

Ironically, with the ever-changing world, students' views on the amount of homework assigned changed once again. In The *State of Our Nation's Youth* Survey (Horatio Alger Association, 2008), 21% of high school students claimed to work on homework for 10 hours or more per week, up 9% since 2005 (Horatio Alger Association, 2008). This change in students' views may stem from a variety of reasons. One of the major reasons for this change may be a result of a student's desire to achieve good grades in order to advance their education. Regardless of the reason why students report doing more homework, the fact remains that currently more students are focused on completing homework. However, it is not clear that completing more homework is in a one-to-one relationship with knowledge acquisition (Cech, 2008).

Development of Meaningful Assignments

Some fear the idea of doing homework for knowledge sake has been lost. A study of 4500 high school students, carried out by Rutgers University (Sohn, 2001) reported that 75% of high school students admitted to cheating on a test in the past year rather than studying more to pass the test. A similar percentage of students claim to have handed in work completed by someone else. Students seemed to find little relevance in completing their own coursework (Sohn, 2001). It has been argued that students obsessed with

grades are more likely to cheat than those not obsessed with grades (Romanowski, 2004). If students remain focused on grades rather than knowledge perhaps the type of homework being assigned needs to be evaluated.

For years homework was seen as a natural extension of any course (Pasi, 2006). However, conversations are currently taking place to discuss the purpose of homework. Homework should be meaningful and purposeful. It should be used to enhance what is currently happening in the course itself (Pasi, 2006). One of the greatest reasons to assign homework is to aid in the immediate retention and understanding of course material (Sullivan & Sequeira, 1996). In order for homework to be effective, it should not be a blanket assignment forcing all students to work at the same pace. Students need to work at their own pace so they can foster the information as they learn it (Sullivan & Sequeira, 1996).

Within the confines of homework, there are generally three types of assignments. The first type of homework is preparation. Care needs to be taken to not overdue this type of homework, as it is to introduce a new topic or idea. The second type of homework is practice. Much of the teacher assigned homework tends to fall in this category, as it is the type given to students to practice or repeat the new skill in a variety of ways. To avoid these assignments from becoming busy work, the assignments need to be carefully selected to ensure it is for practice, not time consumption. The third type of homework is extension homework. Extension assignments go beyond the regular curriculum and usually involve a project or report of some type. Much thought needs to be put into such assignments to ensure they are enhancing the current curriculum and are doable by the student for which it is assigned (Sullivan & Sequeira, 1996).

Student Motivation to Complete Homework

Motivation is sorted into two categories: positive reinforcement and negative reinforcement. How to motivate students can be quite controversial. Many people have strong feelings as to which type of motivation is most effective. Regardless, both types have been used in the education system for quite some time.

Some argue that the way to pull up the bottom students' academic performance is by showing off the top students' academic performance. Many schools do not routinely celebrate academic achievement. However, most schools have pep rallies to show off the athletic achievements of its students. Other schools are changing this way of doing business--after all, the primary purpose of a school is to educate kids. For example, Sycamore High School, Cincinnati, OH, announces its National Merit Scholarship winners over the intercom, immediately after the student has called home to tell their parents/guardians the good news, followed by a celebration of this achievement (Gregg, 2003). Showcasing achievement helps set a culture of success and may help to diminish the number of students that see underachievement as acceptable.

On the flipside, obsession with achieving high grades may lead to negative side effects. Some students are able to attain high grades solely because they know how to play the game well. They know how to jump through the academic hoops necessary to achieving high grades. Many times they are fixated on being told what they need to know and are not focused on learning and independent thinking. According to Romanowski (2004) "Knowledge is considered dispensable after it is used to secure a good grade" (p. 150). The *State of Our Nation's Youth* (Horatio Alger Association, 2008) publication reported that 79% of students believe pressure to get good grades is a

problem, up from 62% in 2001. Furthermore, 45% of high school students report grade pressure as a major problem, up 19 percentage points since 2001 (Horatio Alger Association, 2008). Education is about educating and attaining knowledge and skills, it is not about a specific mark on a paper, be it an “A” or a “0.” Assigning a grade to homework and overall grades in general can be viewed as either positive or negative reinforcement--affecting some but not all students (Cech, 2008).

Studies have found that parent expectations also play a role in a student’s motivation to do homework, especially with younger students. Many students completed their homework because their mom or dad said they had to or because they wanted to make their mom or dad proud (Xu, 2005). Another study evaluated parental involvement with regard to homework. The study included 401, 5th through 9th-grade, students. The study concluded that students regardless of age, gender, and socioeconomic levels were more motivated to do their homework with their parents than they were alone or with a peer. The students that completed their homework with their parents at young ages tended to be higher achievers with higher grade point averages than those that did not do their homework with their parents. The latter students were more likely to do even less homework in high school (Xu, 2005).

Furthermore, students’ interests, personal, and situational beliefs are extremely important in highlighting a student’s motivational influence (Harrison & Treagust, 2001). A student interested in science is more likely to be successful than a student that has little to no interest in science. Students’ goals, intentions, purposes, expectations, and needs are as important as cognitive strategies in concept learning (Harrison & Treagust, 2001). While many different types of motivation exist, the key is to find what motivates each

individual student whether they currently see the importance of homework or importance of learning chemistry.

Assessing Homework

If students are unable to see the value in homework and the ill effect of cheating, then why do so many teachers continue to assign nightly homework? One reason stems from standards based education. A teacher is responsible for covering a specified curriculum, many times to an insurmountable amount. In order to successfully cover the set forth curriculum, homework must be assigned because, as many teachers know, there is not enough time in the day to get through all the material (Perimutter, 1978; Streitberger, 1985). If ridding the educational system of homework is not the answer, then maybe the way homework is assessed needs to be addressed. To grade an assignment that may or may not have been done by a said individual seems illogical if the end result is to be mastery of the subject material.

Today there are many methods for assessing homework. Some teachers still believe in grading all homework and assigning it a point value. Other teachers give students completion points for attempting the assignment. Still other teachers do not believe in grading homework at all or at least having homework figured in to the students' overall grades. These three methods encompass the current thinking about what type of homework will best result in success in the science classroom (O'Connor, 2002).

Assigning an actual grade to an assignment and counting it towards the student's overall grade is one method. It has been used for many years. In the early 1990s, studies were being done to determine the affect of homework grades on a student's overall grade. Concern for grade inflation arose as it was noted that students were receiving higher letter

grades in their academic courses than they were on a minimum competency exam. Looking into the topic, it was noted that there was a large range of weight attached to homework. Homework accounted for anywhere from 0% to 40% of the student's overall grade. It was pointed out that homework must be related to the subject being studied and that the homework should be beneficial to the students' overall academic experience. The homework should be used to help the student perform better on assessments, thus proving the student's knowledge of the subject area. Homework should not be placed into the grade merely for inflation purposes (Knore, 1996).

Another study focused on the effects of grading but took a different approach. Instead of worrying about grade inflation, it is argued that failure is not an option. Homework should be graded but it should only receive one of four markings, "A", "B", "C", or "I" (incomplete). Since homework is to be used for practice, assessing homework assignments with an "I" tells the students that they need to try again and they are not allowed to give up (Brown, 2004).

This idea is echoed through the no zero policy being adopted by some school districts. The teacher's ability to give a student a zero for not completing a homework assignment is under huge scrutiny. If homework is to be for practice, then is it fair to deflate a student's grade because the student did not demonstrate work ethic or show enough effort? Alternatives to assigning a zero include giving the student an incomplete and assessing behavior separately (Guskey, 2004).

Grading for Learning

Grading for learning is a concept that recommends that course grades focus on learning by: 1. Relating grading procedures to learning goals. 2. Using criterion-

referenced performance standards as reference points to determine grades. 3. Limiting the valued attributes included in grades to individual achievement. 4. Sampling student performance (do not include all scores in overall grades). 5. Grading in pencil. 6. Crunching numbers carefully--if at all. 7. Using quality assessments and properly recorded evidence of achievement. 8. Discussing and involving students in assessment, including grading, throughout the teacher/learning process (O'Connor, 2002). These practices are to be put into place in order to ensure accurate grading measures in which the final grade truly reflects what the student has learned about the material/objectives in the course.

Relating grading procedures to learning goals. Many teachers include behavior in their grading methods. Teachers should evaluate the students on the learning goals of the class rather than the methods to which the student achieved mastery of the material (University of Washington, 2010). In order for a teacher's grade book to reflect learning goal mastery, the teacher should set up the grade book according to learning goals/objectives. When deciding on the learning goals, the teacher needs to focus on the items/concepts that he/she wants the students to know or be able to do at the end of the course (University of California at Berkeley, 2010). Creating a goal for every objective that a student must master may not be realistic as most teachers have too much content and too many students. Grouping objectives into a larger strand is a compromise that still allows a grading method to show a true reflection of a student's knowledge base (O'Connor, 2002).

Using criterion-referenced performance standards as reference points to determine grades. Current percentage-based grade scales leave a lot of room for

subjectivity and may not necessarily reflect whether or not a student has mastered the material. Students should be graded on whether or not they have mastered the learning goals set forth by the teacher. The students should be made aware of the learning goals and given specific criteria with which mastery of the goal will be evaluated (University of Washington, 2010). In order to receive a passing grade, the student should master all the learning goals at a set standard unless otherwise decided by the district (O'Connor, 2002). Any student that has mastered all the goals should receive the highest grade possible (Metropolitan School District of Pike Township, 2010). In order to master the learning goals a student may be given both graded and ungraded assignments. The graded assignments should be used to evaluate learning and performance in the course while the ungraded assignments should be used as a learning tool to practice the concept and expose the students to the material prior to evaluation (University of California at Berkeley, 2010).

Limiting the valued attributes included in grades to individual achievement.

The student's attitude, attendance, organizational skills, work ethic, among other classroom behaviors, should be graded separately if at all. Many of these behaviors are reflected negatively in a student's grade and thus it appears that the student has mastered less material. Other behaviors such as group work and extra credit many times lead to inflated grades and are just as problematic as they reflect that the student has mastered more material than they really have. The course grade should only reflect student achievement on the curriculum (Metropolitan School District of Pike Township, 2010). Some classes like math and science may require very specific grading rubrics that focus on correct procedures and answers while grading a drama class may be defined more

broadly (O'Connor, 2002). As not all standards and outcomes may be evaluated with a paper and pen assessment, performance assessments may be used to test individual mastery of a technique or procedure (O'Connor, 2002).

Sampling student performance (do not include all scores in overall grades).

Teachers should use a variety of assessment methods when looking for evidence of a student's strengths and weaknesses. In order to assess clearly, a teacher must distinguish between formative and summative assessments (O'Connor, 2002). In order to educate effectively, a teacher should have a basis of prior knowledge to build on. A teacher can determine the student's base knowledge by administering a diagnostic assessment prior to instruction (McTighe & O'Connor, 2005). Students should be allowed to practice and receive teacher feedback on formative assessments in order to be prepared for the summative assessment (O'Connor, 2002). Furthermore, teachers need to make sure they do not confuse how to do something with formative assessments and the thing being done with summative assessments. Both processes and products are important to be graded both formatively and summatively (Metropolitan School District of Pike Township, 2010). Teachers can keep track of formative assessments with +/- in the grade book but that should not affect the student's grade as they are only to be used as feedback so a student can master the material prior to the summative assessment (O'Connor, 2002).

Grading in pencil. Students learn at different rates and some take more opportunities than others in order to master a skill or content standard. Students should be given credit for mastery of subject matter regardless of the timeframe with which the material was learned (O'Connor, 2002). If the focus of education is mastery of material, it should not matter when the student masters the material. Students should receive

multiple opportunities to demonstrate mastery of learning and should not be limited with capped grades on retakes (Metropolitan School District of Pike Township, 2010).

Numerous real-life tests, such as the driving test and state board exams, allow for retakes and the person taking the test gets credit for passing the test regardless of how many chances they received or when the exam was passed (McTighe & O'Connor, 2005). In the real world, the number of retakes may not be limited but an unlimited number of retakes over an unlimited amount of time is unrealistic in a school setting. There are practical implications that a teacher may put into place with regard to retakes. A teacher may require a student to attend a reteaching or review session or to provide evidence that they have attempted to relearn the information prior to allowing a student to retest (O'Connor, 2002).

Crunching numbers carefully--if at all. Traditional grading favors students that do all their work even if it is not done well. Students that do some work superbly and then do not complete some other work do not usually fare so well in the popular method of using the mean to calculate the student's score (O'Connor, 2002). Giving a student a zero for incomplete, late, or missing work creates an inaccurate representation of achievement (Metropolitan School District of Pike Township, 2010). Furthermore, using an evenly weighted grade scale such as beginning, progressing, proficient, and advanced would offer a more accurate understanding of what level a student has mastered and where he/she is in regard to moving on to the next level. The current method of averaging does not paint a clear picture of whether a student is ready to move on because the method for reaching the percentage awarded may be a mystery including but not limited to zeroes, behavior grades, and formative assessment grades (O'Connor, 2002).

Using quality assessment(s) and properly recorded evidence of achievement.

A teacher must have an open and understandable dialogue with their students regarding how they will be assessed. Many times this communication is provided in written form in a syllabus. Once a teacher has determined their assessment and grading method and has relayed the information to the students, it is important that the instructor is consistent with the syllabus (University of California at Berkeley, 2010). Teachers should use a variety of methods such as portfolios, student-conferencing, and expanded format reporting in order to effectively communicate student achievement (Metropolitan School District of Pike Township, 2010). Regardless of the assessment style, it is important that teachers accurately record the grades in a timely fashion into a format that the students can access and understand. Grade reporting is mandated by most school districts and a teacher must make it work in a practical sense for themselves and their students (O'Connor, 2010).

Discussing and involving students in assessment, including grading, throughout the teacher/learning process. Effective learners set learning goals and self-assess their work prior to handing it in for grading. Rubrics allow students to self-assess their work while they are working on their product in order to achieve the expectations of the assignment (McTighe & O'Connor, 2005). When teachers use rubrics, it is important that the teacher teaches the students how to use the rubric for self-assessment. Prior to handing out a rubric, it may be appropriate for a teacher to seek student input on how they feel a product should be assessed. Involving the students in creating the rubric may help ensure that the students understand how the assignments will be graded and allows

the grading process to be done with students, not to students (Metropolitan School District of Pike Township, 2010; O'Connor, 2002).

Final Thoughts

Unfortunately, these changes in grading practices do not address how to get a student to complete the homework. Sometimes homework is essential to the academic experience. If the power of the often referred to *almighty zero* is taken away from teachers, then what is the next logical step to motivate students to do their assignments?

There is little argument that grades affect how students learn. Grades have both a positive and negative effect on students. For some students grades prompt them to work harder while for other students, grades may provide them with an excuse to give up. Unfortunately, for some students the desire to get a good grade results in cheating and not motivation to study harder. It seems pretty apparent that the focus of education has become an arbitrary number as opposed to learning. Is learning possible without attaching a grade to it? Outcomes based education is supposed to be about outcomes not grades.

If changing the high school way of assessing learning was that easy, it would have been done by now. The elementary school has been doing this type of assessment for years. The necessary evil that prevents high schools from ridding itself of grades is the college application and acceptance process. Colleges need a finite method of comparing one individual to another. They need something measurable to decide if a certain individual may be right for their post-secondary establishment. So, since grades are not going to go away anytime soon, the development of meaningful homework and grading

practices with regard to attainment of knowledge needs to be reassessed. This is particularly true for mastering rigorous high school chemistry coursework.

CHAPTER THREE

Methodology

The purpose of this posttest only study was to determine the impact of ungraded chemistry homework on the formative and summative chemistry assessment scores of 11th-grade students with below average, average, and above average cumulative grade point averages compared to students who completed traditional graded chemistry homework assignments.

Participants

Individuals participating in this study were 11th-grade students enrolled in a chemistry course taught by the predetermined teacher in 2005 or 2008 and completed all four teacher-prepared unit assessments, the district-prepared assessment, and district prepared physical science strand of the science ELO. The students were randomly placed through the registration process.

Number of participants. Study participants ($N = 98$) consisted of six randomly formed arms. The first arm was a group of students with above average chemistry potential who were given teacher assigned but not graded chemistry homework ($n = 17$). The second arm was a group of average students who were given teacher assigned but not graded chemistry homework ($n = 15$). The third arm was a group of below average students who were given teacher assigned but not graded chemistry homework ($n = 19$). The fourth arm was a group of students with above average chemistry potential who were assigned graded chemistry homework ($n = 16$). The fifth arm was a group of average students who were assigned graded chemistry homework ($n = 17$). The sixth arm was a group of below average students who were assigned graded chemistry homework ($n =$

14). Participants in arms one, two, and three were in first semester chemistry in 2008.

Participants in arms four, five, and six were in first semester chemistry in 2005.

Gender of participants. Of the total number of selected subjects that received teacher assigned but not graded homework ($n = 47$) the gender ratio was 25 boys (53%) and 22 girls (47%). Of the total number of selected subjects that received teacher assigned and graded homework ($n = 51$) the gender ratio was 23 boys (45%) and 28 girls (55%). The gender of the study participants was congruent with the research school district's gender demographics.

Age range of participants. The age range for all study participants was from 15 years to 17 years. All participants were in the 11th-grade. The age range of the study participants was congruent with the research school district's age range demographics for 11th-grade students.

Racial and ethnic origin of participants. Of the total number of selected subjects that received teacher assigned but not graded homework ($n = 47$) the ethnic and racial origin of the participants was 41 Caucasian (87%), 3 African American (6%), 1 Hispanic (2%), and 2 Asian/Pacific Islander (4%) students. Of the total number of selected subjects that received teacher assigned and graded homework ($n = 51$) the ethnic and racial origin of the participants was 46 Caucasian (90%), 2 African American (4%), 1 Hispanic (2%), and 2 Asian/Pacific Islander (4%) students. The racial and ethnic origin of the study participants is congruent with the research school district's racial and ethnic demographics.

Inclusion criteria of the participants. Eleventh-grade students who were enrolled in a specific chemistry teacher's chemistry course at the study school during the

first semester of 2005 and the first semester of 2008. Students must have completed all four teacher-prepared chemistry assessments, the district chemistry assessment, and the district science ELO.

Method of participant identification. Students with above average chemistry potential had unweighted GPAs of 3.3 and above at the end of their 10th-grade year. Students with average chemistry potential had unweighted GPAs between 2.86 and 3.3 at the end of their 10th-grade year. Students with below average chemistry potential had unweighted GPAs of 2.86 and below at the end of the 10th-grade year. The 2005 chemistry students received teacher assigned but not graded chemistry homework while the 2008 chemistry students received teacher assigned and graded chemistry homework.

Description of Procedures

Research design. This posttest-only six-group comparative efficacy study design is displayed in the following notation:

Group 1 $X_1 Y_1 O_1$

Group 2 $X_1 Y_2 O_1$

Group 3 $X_1 Y_3 O_1$

Group 4 $X_1 Y_4 O_1$

Group 5 $X_1 Y_5 O_1$

Group 6 $X_1 Y_6 O_1$

Group 1 = study participants #1. Eleventh-grade students with above average chemistry potential who completed chemistry with teacher assigned but not graded homework ($n = 17$).

Group 2 = study participants #2. Eleventh -grade students with average chemistry potential who completed chemistry with teacher assigned but not graded homework ($n = 15$).

Group 3 = study participants #3. Eleventh -grade students with below average chemistry potential who completed chemistry with teacher assigned but not graded homework ($n = 19$).

Group 4 = study participants #4. Eleventh -grade students with above average chemistry potential who completed chemistry with teacher assigned and graded homework ($n = 16$).

Group 5 = study participants #5. Eleventh -grade students with average chemistry potential who completed chemistry with teacher assigned and graded homework ($n = 17$).

Group 6 = study participants #6. Eleventh -grade students with below average chemistry potential who completed chemistry with teacher assigned and graded homework ($n = 14$).

X₁ = study constant. All study students were randomly assigned to and completed the same introductory chemistry course.

Y₁ = study independent variables, homework and achievement, condition #1. Students with above average chemistry potential with teacher assigned but not graded chemistry homework.

Y₂ = study independent variables, homework and achievement, condition #2. Students with average chemistry potential with teacher assigned but not graded chemistry homework.

Y₃ = study independent variables, homework and achievement, condition #3.

Students with below average chemistry potential with teacher assigned but not graded chemistry homework.

Y₄ = study independent variables, homework and achievement, condition #4.

Students with above average chemistry potential with teacher assigned and graded chemistry homework.

Y₅ = study independent variables, homework and achievement, condition #5.

Students with average cumulative chemistry potential with teacher assigned and graded chemistry homework.

Y₆ = study independent variables, homework and achievement, condition #6.

Students with below average chemistry potential with teacher assigned and graded chemistry homework.

O₁ = study posttest dependent measures. (1) Chemistry homework completion rates in both ungraded and traditional graded 11th-grade chemistry sections. (2) Teacher prepared 11th-grade chemistry state standards-based classroom unit assessments for (a) matter, (b) atoms, (c) naming, and (d) reactions scores. (3) District prepared 11th-grade global chemistry assessment score. (4) District graduation requirement physical science strand 11th-grade science ELO score.

Implementation of the Independent Variables

The independent variables for this study were chemistry students that received teacher assigned but not graded homework and chemistry students that received teacher assigned and graded homework. The two groups of chemistry students were split into subgroups based on their 10th-grade cumulative GPA. By classifying students based on

their academic potential, a more accurate comparison was made between the two homework groups. The research school supported the chemistry homework grading methods of this study.

The purpose of this study was to determine the impact of teacher assigned but not graded chemistry homework on the formative and summative chemistry assessment scores of 11th-grade students with above average, average, and below average chemistry potential compared to the formative and summative chemistry assessment scores of 11th-grade students with above average, average, and below average chemistry potential who completed teacher assigned and graded chemistry homework assignments.

The study analyzed 2005 posttest data to 2008 posttest data to determine student academic achievement outcomes across three academic levels and two teacher homework evaluation methods on teacher prepared 11th-grade assessments, district prepared 11th-grade assessment, and district graduation requirement physical science strand 11th-grade science ELO assessment.

Dependent Measures

The following research questions focused on the dependent variables, specifically homework completion rates, teacher prepared assessment scores in the areas of (a) matter, (b) atoms, (c) naming, and (d) reactions, district prepared global assessment, and district science ELO assessment.

Research Questions, Sub-Questions, and Data Analysis

The following posttest-posttest research question was used to analyze students with above average chemistry potential who were given teacher assigned but not graded chemistry homework and students with above average chemistry potential who were

given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on teacher-prepared assessments.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #1. Do students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of the unit posttest 11th-grade chemistry scores as measured by the teacher prepared 11th-grade criterion-referenced tests (CRTs) for (a) matter, (b) atoms, (c) naming, and (d) reactions?

Sub-Question 1a. Are the teacher prepared posttest 11th-grade end of unit matter CRT assessment scores the same for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-Question 1b. Are the teacher prepared posttest 11th-grade end of unit atoms CRT assessment scores the same for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework and students with above average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-question 1c. Are the teacher prepared posttest 11th-grade end of unit naming CRT assessment scores the same for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework and

students with above average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-question 1d. Are the teacher prepared posttest 11th-grade end of unit reactions CRT assessment scores the same for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework and students with above average chemistry potential who were given teacher assigned and graded chemistry homework?

Analysis. Research Sub-Questions #1a, 1b, 1c, and 1d were analyzed using independent t tests to examine the statistical significance of the difference between students who were given teacher assigned but not graded chemistry homework and students who were given teacher assigned and graded chemistry homework ending posttest 11th-grade compared to ending posttest 11th-grade CRT scores. Because multiple statistical tests were conducted and no theoretical direction could be predicted for the results, a one-tailed, .05 alpha level of confidence was employed to control for Type 1 errors. Means and standard deviations were displayed in tables.

The following posttest-posttest research question was used to analyze students with average chemistry potential who were given teacher assigned but not graded chemistry homework and students with average chemistry potential who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on teacher-prepared assessments.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement Research Question #2. Do students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average

chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of the unit posttest 11th-grade chemistry scores as measured by the teacher prepared 11th-grade CRTs for (a) matter, (b) atoms, (c) naming, and (d) reactions?

Sub-Question 2a. Are the teacher prepared posttest 11th-grade end of unit matter CRT assessment scores the same for students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-Question 2b. Are the teacher prepared posttest 11th-grade end of unit atoms CRT assessment scores the same for students with average chemistry potential who were given teacher assigned but not graded chemistry homework and students with average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-question 2c. Are the teacher prepared posttest 11th-grade end of unit naming CRT assessment scores the same for students with average chemistry potential who were given teacher assigned but not graded chemistry homework and students with average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-question 2d. Are the teacher prepared posttest 11th-grade end of unit reactions CRT assessment scores the same for students with average chemistry potential who were given teacher assigned but not graded chemistry homework and students with

average chemistry potential who were given teacher assigned and graded chemistry homework?

Analysis. Research Sub-Questions #2a, 2b, 2c, and 2d were analyzed using independent *t* tests to examine the statistical significance of the difference between students who were given teacher assigned but not graded chemistry homework and students who were given teacher assigned and graded chemistry homework ending posttest 11th-grade compared to ending posttest 11th-grade CRT scores. Because multiple statistical tests were conducted and no theoretical direction could be predicted for the results, a one-tailed, .05 alpha level of confidence was employed to control for Type 1 errors. Means and standard deviations were displayed in tables.

The following posttest-posttest research question was used to analyze students with below average chemistry potential who were given teacher assigned but not graded chemistry homework and students with below average chemistry potential who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on teacher-prepared assessments.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #3. Do students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of the unit posttest 11th-grade chemistry scores as measured by the teacher prepared 11th-grade CRTs for (a) matter, (b) atoms, (c) naming, and (d) reactions?

Sub-Question 3a. Are the teacher prepared posttest 11th-grade end of unit matter CRT assessment scores the same for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-Question 3b. Are the teacher prepared posttest 11th-grade end of unit atoms CRT assessment scores the same for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework and students with below average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-question 3c. Are the teacher prepared posttest 11th-grade end of unit naming CRT assessment scores the same for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework and students with below average chemistry potential who were given teacher assigned and graded chemistry homework?

Sub-question 3d. Are the teacher prepared posttest 11th-grade end of unit reactions CRT assessment scores the same for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework and students with below average chemistry potential who were given teacher assigned and graded chemistry homework?

Analysis. Research Sub-Questions #3a, 3b, 3c, and 3d were analyzed using independent t tests to examine the statistical significance of the difference between students who were given teacher assigned but not graded chemistry homework and

students who were given teacher assigned and graded chemistry homework ending posttest 11th-grade compared to ending posttest 11th-grade CRT scores. Because multiple statistical tests were conducted and no theoretical direction could be predicted for the results, a one-tailed, .05 alpha level of confidence was employed to control for Type 1 errors. Means and standard deviations were displayed in tables.

The following posttest-posttest research question was used to analyze all students who were given teacher assigned but not graded chemistry homework and all students who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the district prepared assessment.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #4. Do all students who were given teacher assigned but not graded chemistry homework compared to all students who were given teacher assigned and graded chemistry homework have congruent or different end of the unit posttest 11th-grade chemistry scores as measured by the teacher prepared 11th-grade CRTs for (a) matter, (b) atoms, (c) naming, and (d) reactions?

Sub-Question 4a. Are the teacher prepared posttest 11th-grade end of unit matter CRT assessment scores the same for all students who were given teacher assigned but not graded chemistry homework compared to all students who were given teacher assigned and graded chemistry homework?

Sub-Question 4b. Are the teacher prepared posttest 11th-grade end of unit atoms CRT assessment scores the same for all students who were given teacher assigned but not graded chemistry homework and students all students who were given teacher assigned and graded chemistry homework?

Sub-question 4c. Are the teacher prepared posttest 11th-grade end of unit naming CRT assessment scores the same for all students who were given teacher assigned but not graded chemistry homework and all students who were given teacher assigned and graded chemistry homework?

Sub-question 4d. Are the teacher prepared posttest 11th-grade end of unit reactions CRT assessment scores the same for all students who were given teacher assigned but not graded chemistry homework and all students who were given teacher assigned and graded chemistry homework?

Analysis. Research Sub-Questions #4a, 4b, 4c, and 4d were analyzed using independent t tests to examine the statistical significance of the difference between students who were given teacher assigned but not graded chemistry homework and students who were given teacher assigned and graded chemistry homework ending posttest 11th-grade compared to ending posttest 11th-grade CRT scores. Because multiple statistical tests were conducted and no theoretical direction could be predicted for the results, a one-tailed, .05 alpha level of confidence was employed to control for Type 1 errors. Means and standard deviations were displayed in tables.

The following posttest-posttest research question was used to analyze students with above average chemistry potential who were given teacher assigned but not graded chemistry homework and students with above average chemistry potential who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the district prepared assessment.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement Research Question #5. Do students with above average chemistry potential who were

given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of the course posttest 11th-grade chemistry scores as measured by (a) the district prepared 11th-grade CRT?

Sub-question 5a. Are the district prepared posttest 11th-grade end of semester CRT assessment scores the same for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework?

Analysis. Research Sub-Question #5a was analyzed using independent *t* tests to examine the statistical significance of the difference between students who were given teacher assigned but not graded chemistry homework and students who were given teacher assigned and graded chemistry homework ending posttest 11th-grade compared to ending posttest 11th-grade CRT scores. Because multiple statistical tests were conducted and no theoretical direction could be predicted for the results, a one-tailed, .05 alpha level of confidence was employed to control for Type 1 errors. Means and standard deviations were displayed in tables.

The following posttest-posttest research question was used to analyze students with average chemistry potential who were given teacher assigned but not graded chemistry homework and students with average chemistry potential who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the district prepared assessment.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #6. Do students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of the course posttest 11th-grade chemistry scores as measured by (a) the district prepared 11th-grade CRT?

Sub-question 6a. Are the district prepared posttest 11th-grade end of semester CRT assessment scores the same for students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework?

Analysis. Research Sub-Question #6a was analyzed using independent *t* tests to examine the statistical significance of the difference between students who were given teacher assigned but not graded chemistry homework and students who were given teacher assigned and graded chemistry homework ending posttest 11th-grade compared to ending posttest 11th-grade CRT scores. Because multiple statistical tests were conducted and no theoretical direction could be predicted for the results, a one-tailed, .05 alpha level of confidence was employed to control for Type 1 errors. Means and standard deviations were displayed in tables.

The following posttest-posttest research question was used to analyze students with below average chemistry potential who were given teacher assigned but not graded chemistry homework and students with below average chemistry potential who were

given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the district prepared assessment.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #7. Do students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of the course posttest 11th-grade chemistry scores as measured by (a) the district prepared 11th-grade CRT?

Sub-question 7a. Are the district prepared posttest 11th-grade end of semester CRT assessment scores the same for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework?

Analysis. Research Sub-Question #7a was analyzed using independent *t* tests to examine the statistical significance of the difference between students who were given teacher assigned but not graded chemistry homework and students who were given teacher assigned and graded chemistry homework ending posttest 11th-grade compared to ending posttest 11th-grade CRT scores. Because multiple statistical tests were conducted and no theoretical direction could be predicted for the results, a one-tailed, .05 alpha level of confidence was employed to control for Type 1 errors. Means and standard deviations were displayed in tables.

The following posttest-posttest research question was used to analyze all students who were given teacher assigned but not graded chemistry homework and all students

who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the district prepared assessment.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #8. Do all students who were given teacher assigned but not graded chemistry homework compared to all students who were given teacher assigned and graded chemistry homework have congruent or different end of the course posttest 11th-grade chemistry scores as measured by (a) the district prepared 11th-grade CRT?

Sub-question 8a. Are the district prepared posttest 11th-grade end of semester CRT assessment scores the same for all students who were given teacher assigned but not graded chemistry homework compared to all students who were given teacher assigned and graded chemistry homework?

Analysis. Research Sub-Question #8a was analyzed using independent *t* tests to examine the statistical significance of the difference between students who were given teacher assigned but not graded chemistry homework and students who were given teacher assigned and graded chemistry homework ending posttest 11th-grade compared to ending posttest 11th-grade CRT scores. Because multiple statistical tests were conducted and no theoretical direction could be predicted for the results, a one-tailed, .05 alpha level of confidence was employed to control for Type 1 errors. Means and standard deviations were displayed in tables.

The following posttest-posttest research question was used to analyze students with above average chemistry potential who were given teacher assigned but not graded chemistry homework and students with above average chemistry potential who were

given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the physical science strand of the science ELO.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #9. Do students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of district required science outcomes posttest 11th-grade chemistry scores as measured by (a) the district graduation requirement physical science strand of the 11th-grade science ELO?

Sub-question 9a. Are the district graduation requirement physical science strand of the 11th-grade science ELO scores the same for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework?

Analysis. Research Sub-Question #9a was analyzed using independent *t* tests to examine the statistical significance of the difference between students who were given teacher assigned but not graded chemistry homework and students who were given teacher assigned and graded chemistry homework ending posttest 11th-grade compared to ending posttest 11th-grade CRT scores. Because multiple statistical tests were conducted and no theoretical direction could be predicted for the results, a one-tailed, .05 alpha level of confidence was employed to control for Type 1 errors. Means and standard deviations were displayed in tables.

The following posttest-posttest research question was used to analyze students with average chemistry potential who were given teacher assigned but not graded chemistry homework and students with average chemistry potential who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the physical science strand of the science ELO.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #10. Do students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of district required science outcomes posttest 11th-grade chemistry scores as measured by (a) the district graduation requirement physical science strand of the 11th-grade science ELO?

Sub-question 10a. Are the district graduation requirement physical science strand of the 11th-grade science ELO scores the same for students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework?

Analysis. Research Sub-Question #10a was analyzed using independent *t* tests to examine the statistical significance of the difference between students who were given teacher assigned but not graded chemistry homework and students who were given teacher assigned and graded chemistry homework ending posttest 11th-grade compared to ending posttest 11th-grade CRT scores. Because multiple statistical tests were conducted and no theoretical direction could be predicted for the results, a one-tailed, .05

alpha level of confidence was employed to control for Type 1 errors. Means and standard deviations were displayed in tables.

The following posttest-posttest research question was used to analyze students with below average chemistry potential who were given teacher assigned but not graded chemistry homework and students with below average chemistry potential who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the physical science strand of the science ELO.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #11. Do students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework have congruent or different end of district required science outcomes posttest 11th-grade chemistry scores as measured by (a) the district graduation requirement physical science strand of the 11th-grade science ELO?

Sub-question 11a. Are the district graduation requirement physical science strand of the 11th-grade science ELO scores the same for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework?

Analysis. Research Sub-Question #11a was analyzed using independent *t* tests to examine the statistical significance of the difference between students who were given teacher assigned but not graded chemistry homework and students who were given teacher assigned and graded chemistry homework ending posttest 11th-grade compared

to ending posttest 11th-grade CRT scores. Because multiple statistical tests were conducted and no theoretical direction could be predicted for the results, a one-tailed, .05 alpha level of confidence was employed to control for Type 1 errors. Means and standard deviations were displayed in tables.

The following posttest-posttest research question was used to analyze all students who were given teacher assigned but not graded chemistry homework and all students who were given teacher assigned and graded chemistry homework measuring criterion-referenced chemistry outcomes on the physical science strand of the science ELO.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #12. Do all students who were given teacher assigned but not graded chemistry homework compared to all students who were given teacher assigned and graded chemistry homework have congruent or different end of district required science outcomes posttest 11th-grade chemistry scores as measured by (a) the district graduation requirement physical science strand of the 11th-grade science ELO?

Sub-question 12a. Are the district graduation requirement physical science strand of the 11th-grade science ELO scores the same for all students who were given teacher assigned but not graded chemistry homework compared to all students who were given teacher assigned and graded chemistry homework?

Analysis. Research Sub-Question #12a was analyzed using independent *t* tests to examine the statistical significance of the difference between students who were given teacher assigned but not graded chemistry homework and students who were given teacher assigned and graded chemistry homework ending posttest 11th-grade compared to ending posttest 11th-grade CRT scores. Because multiple statistical tests were

conducted and no theoretical direction could be predicted for the results, a one-tailed, .05 alpha level of confidence was employed to control for Type 1 errors. Means and standard deviations were displayed in tables.

The following posttest-posttest research question was used to rank order correlate all students' not graded chemistry homework averages and graded chemistry assessment averages.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #13. What is the relationship between the Spearman rank order correlation coefficient of all students not graded chemistry homework averages and their graded chemistry assessment averages?

Sub-question 13a. Is there a significant relationship between the rank orders of all students not graded chemistry homework averages and graded chemistry assessment averages?

Analysis. Research Sub-Questions #13a was analyzed using a Spearman rank order correlation coefficient of not graded chemistry homework averages and the rank order of graded chemistry assessment averages. A .05 alpha level was employed to test for significance. Rank order relationships were displayed in tables and the corresponding coefficient of determination was displayed in *Figure 1*.

The following posttest-posttest research question was used to rank order correlate all students' graded chemistry homework averages and graded chemistry assessment averages.

Overarching Posttest-Posttest Criterion-Referenced Chemistry Achievement

Research Question #14. What is the relationship between the Spearman rank order

correlation coefficient of all students graded chemistry homework averages and their graded chemistry assessment averages?

Sub-question 14a. Is there a significant relationship between the rank orders of all students graded chemistry homework averages and graded chemistry assessment averages?

Analysis. Research Sub-Questions #14a was analyzed using a Spearman rank order correlation coefficient of graded chemistry homework averages and the rank order of graded chemistry assessment averages. A .05 alpha level was employed to test for significance. Rank order relationships were displayed in tables and the corresponding coefficient of determination was displayed in *Figure 2*.

Data Collection Procedures

All student achievement data was retrospectively, archival, and routinely collected school information. Permission from the appropriate school research personnel was obtained. Non-coded numbers were used to display individual de-identified achievement data. Aggregated group data, descriptive statistics, and inferential statistical analysis was utilized and reported with means and standard deviations in tables.

Performance site. The research was conducted in the public school setting through normal educational practices. The study procedure did not interfere in any way with the normal educational practices of the public schools and did not involve coercion or discomfort of any kind. The study was approved first by the Director of Planning and Evaluation for Millard Public Schools and then the University of Nebraska Medical Center/University of Nebraska at Omaha Joint Institutional Review Board (IRB) for the Protection of Human Subjects. Data was stored on computer drives for statistical

analysis. Data and computer flash drives were stored in a locked records vault. No individual identifiers were attached to the data.

Confidentiality. Non-coded numbers were used to display individual de-identified achievement and skills data. Aggregated group data, descriptive statistics, and parametric statistical analysis were utilized and reported as means and standard deviations on tables.

Institutional Review Board (IRB) for the protection of Human Subjects

Approval Category. The exemption categories for this study were provided under 45CFR.101(b) categories 1 and 4. The research was conducted using routinely collected archival data. A letter of support from the district was provided for IRB review.

CHAPTER FOUR

Results

Purpose of the Study

The purpose of this study was to determine the impact of teacher assigned but not graded chemistry homework on the formative and summative chemistry assessment scores of 11th-grade students with above average, average, and below average chemistry potential compared to the formative and summative chemistry assessment scores of 11th-grade students with above average, average, and below average chemistry potential who completed teacher assigned and graded chemistry homework assignments.

The study analyzed 2005 posttest data compared to 2008 posttest data to determine student academic achievement outcomes across three academic levels, above average, average, and below average chemistry potential, and two teacher homework evaluation methods on teacher prepared 11th-grade chemistry assessments for matter, atoms, naming, and reactions, district prepared 11th-grade end of course final assessment, and district graduation requirement physical science strand 11th-grade science Essential Learner Outcome assessment. Permission from the appropriate school research personnel was obtained before data were collected and analyzed.

Table 1 displays demographic information of individual 11th-grade students completing first semester chemistry coursework with not graded or graded homework.

Research Question #1

The first posttest-only hypothesis was tested using the independent t test. The first hypothesis comparing students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with

above average chemistry potential who were given teacher assigned and graded chemistry homework 11th-grade chemistry scores for teacher prepared 11th-grade criterion-referenced assessments for matter, atoms, naming, and reactions results were displayed in Table 2. As seen in Table 2, the null hypothesis was rejected for one of the measured chemistry achievement comparisons between students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework for the subtest matter. The null hypothesis was not rejected for three of the measured chemistry achievement comparisons between students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework for the subtests atoms, naming, and reactions. The not graded chemistry homework matter score ($M = 95.47$, $SD = 15.05$) compared to the graded chemistry homework matter score ($M = 104.81$, $SD = 13.81$) was statistically significantly different, $t(31) = -1.85$, $p = .04$ (one-tailed), $d = 0.65$. The not graded chemistry homework atoms score ($M = 97.55$, $SD = 15.01$) compared to the graded chemistry homework atoms score ($M = 102.61$, $SD = 15.02$) was not statistically significantly different, $t(31) = -0.97$, $p = .17$ (one-tailed), $d = 0.34$. The not graded chemistry homework naming score ($M = 99.51$, $SD = 13.72$) compared to the graded chemistry homework naming score ($M = 100.53$, $SD = 16.70$) was not statistically significantly different, $t(31) = -0.19$, $p = .42$ (one-tailed), $d = 0.07$. The not graded chemistry homework reactions score ($M = 100.30$, $SD = 15.23$) compared

to the graded chemistry homework reactions score ($M = 99.69$, $SD = 15.25$) was not statistically significantly different, $t(31) = 0.12$, $p = .45$ (one-tailed), $d = 0.04$.

Research Question #2

The second posttest-only hypothesis was tested using the independent t test. The second hypothesis comparing students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework 11th-grade chemistry scores for teacher prepared 11th-grade criterion-referenced assessments for matter, atoms, naming, and reactions results were displayed in Table 3. As seen in Table 3, the null hypothesis was rejected for one of the measured chemistry achievement comparisons between students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework for the subtest matter. The null hypothesis was not rejected for three of the measured chemistry achievement comparisons between students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework for the subtests atoms, naming, and reactions. The not graded chemistry homework matter score ($M = 94.76$, $SD = 13.82$) compared to the graded chemistry homework matter score ($M = 106.70$, $SD = 11.44$) was statistically significantly different, $t(30) = -2.67$, $p = .006$ (one-tailed), $d = 0.95$. The not graded chemistry homework atoms score ($M = 98.36$, $SD = 15.29$) compared to the graded chemistry homework atoms score ($M = 102.40$, $SD = 14.86$) was not statistically

significantly different, $t(30) = -0.76$, $p = .23$ (one-tailed), $d = 0.27$. The not graded chemistry homework naming score ($M = 98.97$, $SD = 12.64$) compared to the graded chemistry homework naming score ($M = 102.63$, $SD = 15.78$) was not statistically significantly different, $t(30) = -0.72$, $p = .24$ (one-tailed), $d = 0.26$. The not graded chemistry homework reactions score ($M = 100.48$, $SD = 12.79$) compared to the graded chemistry homework reactions score ($M = 101.14$, $SD = 16.15$) was not statistically significantly different, $t(30) = -0.13$, $p = .45$ (one-tailed), $d = 0.05$.

Research Question #3

The third posttest-only hypothesis was tested using the independent t test. The third hypothesis comparing students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework 11th-grade chemistry scores for teacher prepared 11th-grade criterion-referenced assessments for matter, atoms, naming, and reactions results were displayed in Table 4. As seen in Table 4, the null hypothesis was rejected for one of the measured chemistry achievement comparisons between students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework for the subtest matter. The null hypothesis was not rejected for three of the measured chemistry achievement comparisons between students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework for the

subtests atoms, naming, and reactions. The not graded chemistry homework matter score ($M = 95.09$, $SD = 15.62$) compared to the graded chemistry homework matter score ($M = 106.67$, $SD = 11.52$) was statistically significantly different, $t(31) = -2.34$, $p = .01$ (one-tailed), $d = 0.85$. The not graded chemistry homework atoms score ($M = 98.87$, $SD = 14.94$) compared to the graded chemistry homework atoms score ($M = 101.54$, $SD = 15.52$) was not statistically significantly different, $t(31) = -0.50$, $p = .31$ (one-tailed), $d = 0.40$. The not graded chemistry homework naming score ($M = 97.52$, $SD = 16.57$) compared to the graded chemistry homework naming score ($M = 103.37$, $SD = 12.36$) was not statistically significantly different, $t(31) = -1.11$, $p = .14$ (one-tailed), $d = 0.40$. The not graded chemistry homework reactions score ($M = 97.78$, $SD = 16.46$) compared to the graded chemistry homework reactions score ($M = 103.01$, $SD = 12.70$) was not statistically significantly different, $t(31) = -0.99$, $p = .17$ (one-tailed), $d = 0.36$.

Research Question #4

The fourth posttest-only hypothesis was tested using the independent t test. The fourth hypothesis comparing all students with above average, average, and below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework 11th-grade chemistry scores for teacher prepared 11th-grade criterion-referenced assessments for matter, atoms, naming, and reactions results were displayed in Table 5. As seen in Table 5, the null hypothesis was rejected for one of the measured chemistry achievement comparisons between all students with above average, average, and below average chemistry potential who were given teacher assigned but not graded chemistry homework

compared to all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework for the subtest matter. The null hypothesis was not rejected for three of the measured chemistry achievement comparisons between all students with above average, average, and below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework for the subtests atoms, naming, and reactions. The not graded chemistry homework matter score ($M = 95.12$, $SD = 16.28$) compared to the graded chemistry homework matter score ($M = 105.29$, $SD = 11.45$) was statistically significantly different, $t(96) = -3.55$, $p = .0003$ (one-tailed), $d = 0.73$. The not graded chemistry homework atoms score ($M = 98.35$, $SD = 15.03$) compared to the graded chemistry homework atoms score ($M = 101.79$, $SD = 14.91$) was not statistically significantly different, $t(96) = -1.14$, $p = .13$ (one-tailed), $d = 0.23$. The not graded chemistry homework naming score ($M = 98.38$, $SD = 15.44$) compared to the graded chemistry homework naming score ($M = 101.76$, $SD = 14.48$) was not statistically significantly different, $t(96) = -1.12$, $p = .13$ (one-tailed), $d = 0.23$. The not graded chemistry homework reactions score ($M = 99.00$, $SD = 15.68$) compared to the graded chemistry homework reactions score ($M = 101.09$, $SD = 14.32$) was not statistically significantly different, $t(96) = -0.69$, $p = .25$ (one-tailed), $d = 0.14$.

Research Question #5

The fifth posttest-only hypothesis was tested using the independent t test. The fifth hypothesis comparing students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with

above average chemistry potential who were given teacher assigned and graded chemistry homework 11th-grade chemistry scores for district prepared final chemistry assessment results were displayed in Table 6. As seen in Table 6, the null hypothesis was rejected for measured chemistry achievement comparisons between students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework for the district prepared final chemistry assessment. The not graded chemistry homework district prepared final chemistry assessment score ($M = 93.09$, $SD = 13.02$) compared to the graded chemistry homework district prepared final chemistry assessment score ($M = 107.35$, $SD = 13.69$) was statistically significantly different, $t(31) = -3.07$, $p = .002$ (one-tailed), $d = 1.07$.

Research Question #6

The sixth posttest-only hypothesis was tested using the independent t test. The sixth hypothesis comparing students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework 11th-grade chemistry scores for district prepared final chemistry assessment results were displayed in Table 6. As seen in Table 6, the null hypothesis was not rejected for measured chemistry achievement comparisons between students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework for the district prepared final chemistry assessment. The not graded chemistry homework district prepared final chemistry assessment score ($M = 99.14$, $SD =$

10.43) compared to the graded chemistry homework district prepared final chemistry assessment score ($M = 100.76$, $SD = 18.42$) was not statistically significantly different, $t(30) = -0.30$, $p = .38$ (one-tailed), $d = 0.11$.

Research Question #7

The seventh posttest-only hypothesis was tested using the independent t test. The seventh hypothesis comparing students with below chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework 11th-grade chemistry scores for district prepared final chemistry assessment results were displayed in Table 6. As seen in Table 6, the null hypothesis was rejected for measured chemistry achievement comparisons between students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework for the district prepared final chemistry assessment. The not graded chemistry homework district prepared final chemistry assessment score ($M = 95.23$, $SD = 15.38$) compared to the graded chemistry homework district prepared final chemistry assessment score ($M = 106.48$, $SD = 12.15$) was statistically significantly different, $t(31) = -2.26$, $p = .02$ (one-tailed), $d = 0.82$.

Research Question #8

The eighth posttest-only hypothesis was tested using the independent t test. The eighth hypothesis comparing all students with above average, average, and below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to all students with above average, average, and below average chemistry

potential who were given teacher assigned and graded chemistry homework 11th-grade chemistry scores for district prepared final chemistry assessment results were displayed in Table 6. As seen in Table 6, the null hypothesis was rejected for measured chemistry achievement comparisons between all students with above average, average, and below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework for the district prepared final chemistry assessment. The not graded chemistry homework district prepared final chemistry assessment score ($M = 96.37$, $SD = 13.45$) compared to the graded chemistry homework district prepared final chemistry assessment score ($M = 103.94$, $SD = 15.72$) was statistically significantly different, $t(96) = -2.56$, $p = .006$ (one-tailed), $d = 0.52$.

Research Question #9

The ninth posttest-only hypothesis was tested using the independent t test. The ninth hypothesis comparing students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded chemistry homework 11th-grade physical science strand scores of the district prepared Essential Learner Outcome graduation requirement assessment were displayed in Table 7. As seen in Table 7, the null hypothesis was rejected for measured physical science achievement comparisons between students with above average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with above average chemistry potential who were given teacher assigned and graded

chemistry homework for the physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment. The not graded chemistry homework physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment score ($M = 94.89$, $SD = 13.61$) compared to the graded chemistry homework physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment score ($M = 105.40$, $SD = 15.05$) was statistically significantly different, $t(31) = -2.11$, $p = .02$ (one-tailed), $d = 0.73$.

Research Question #10

The tenth posttest-only hypothesis was tested using the independent t test. The tenth hypothesis comparing students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework 11th-grade physical science strand scores of the district prepared Essential Learner Outcome graduation requirement assessment were displayed in Table 7. As seen in Table 7, the null hypothesis was rejected for measured physical science achievement comparisons between students with average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with average chemistry potential who were given teacher assigned and graded chemistry homework for the physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment. The not graded chemistry homework physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment score ($M = 95.28$, $SD = 15.09$) compared to the graded chemistry homework physical science strand of the district prepared Essential Learner Outcome graduation requirement

assessment score ($M = 104.15$, $SD = 13.98$) was statistically significantly different, $t(30) = -1.73$, $p = .04$ (one-tailed), $d = 0.61$.

Research Question #11

The eleventh posttest-only hypothesis was tested using the independent t test. The eleventh hypothesis comparing students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework 11th-grade physical science strand scores of the district prepared Essential Learner Outcome graduation requirement assessment were displayed in Table 7. As seen in Table 7, the null hypothesis was not rejected for measured physical science achievement comparisons between students with below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to students with below average chemistry potential who were given teacher assigned and graded chemistry homework for the physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment. The not graded chemistry homework physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment score ($M = 100.25$, $SD = 13.75$) compared to the graded chemistry homework physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment score ($M = 99.62$, $SD = 17.21$) was not statistically significantly different, $t(31) = 0.12$, $p = .45$ (one-tailed), $d = 0.04$.

Research Question #12

The twelfth posttest-only hypothesis was tested using the independent t test. The twelfth hypothesis comparing all students with above average, average, and below

average chemistry potential who were given teacher assigned but not graded chemistry homework compared to all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework 11th-grade physical science strand scores of the district prepared Essential Learner Outcome graduation requirement assessment were displayed in Table 7. As seen in Table 7, the null hypothesis was rejected for measured physical science achievement comparisons between all students with above average, average, and below average chemistry potential who were given teacher assigned but not graded chemistry homework compared to all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework for the physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment. The not graded chemistry homework physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment score ($M = 97.16$, $SD = 13.88$) compared to the graded chemistry homework physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment score ($M = 103.12$, $SD = 15.63$) was statistically significantly different, $t(96) = -2.00$, $p = .02$ (one-tailed), $d = 0.40$.

Research Question #13

Means and standard deviations of all students completed but not graded chemistry homework averages and chemistry assessment averages are found in Table 8. As seen in Table 8 the mean not graded chemistry homework average was 63.84 ($SD = 20.12$) and the mean graded chemistry assessment average was 73.35 ($SD = 9.98$). The thirteenth hypothesis was tested using a Spearman rank order coefficient of correlation

(r_s) to determine the nature of the relationship between not graded chemistry homework averages and graded chemistry assessment averages. The result of r_s displayed in Table 8 was statistically significantly different where $r(df = 11) = .9735, p < .001$. The coefficient of determination (95%) was displayed in *Figure 1*. While not implying causality this study finding suggests that students who complete more not graded chemistry homework had a higher probability of improving their chemistry assessment scores regardless of their chemistry potential.

Research Question #14

Means and standard deviations of all students completed and graded chemistry homework averages and chemistry assessment averages are found in Table 9. As seen in Table 9 the mean graded chemistry homework average was 74.07 ($SD = 12.82$) and the mean graded chemistry assessment average was 77.93 ($SD = 9.47$). The fourteenth hypothesis was tested using a Spearman rank order coefficient of correlation (r_s) to determine the nature of the relationship between graded chemistry homework averages and graded chemistry assessment averages. The result of r_s displayed in Table 9 was statistically significantly different where $r(df = 11) = .9073, p < .001$. The coefficient of determination (82%) was displayed in *Figure 2*. While not implying causality this study finding suggests that students who complete more graded chemistry homework had a higher probability of improving their chemistry assessment scores regardless of their chemistry potential.

Table 1

Demographic Information of Individual 11th-Grade Students Completing First Semester Chemistry Coursework With Not Graded or Graded Homework

Chemistry Potential and Not Graded or Graded Homework Condition

Data	<u>Above Average</u> Not Graded/Graded	<u>Average</u> Not Graded/Graded	<u>Below Average</u> Not Graded/Graded
Gender			
Girls	10/ 6	6/ 8	12/ 8
Boys	7/10	9/ 9	7/ 6
Totals	17/16	15/17	19/14
Ethnicity			
White	16/16	14/16	16/ 9
Black	0/ 0	0/ 1	2/ 2
Hispanic	0/ 0	0/ 0	1/ 1
Asian	1/ 0	1/ 0	0/ 2
Totals	17/16	15/17	19/14

Note. All students were in attendance in the research school for the 11th-grade and received a grade for completing first semester chemistry.

Table 2

Students With Above Average Chemistry Potential Who Were Given Teacher Assigned But Not Graded Chemistry Homework Compared to Students With Above Average Chemistry Potential Who Were Given Teacher Assigned and Graded Chemistry Homework 11th-Grade Chemistry Scores for Teacher Prepared 11th-Grade Criterion-Referenced Tests for Matter, Atoms, Naming, and Reactions

<i>Students With Above Average Chemistry Potential</i>							
Measure	Assigned But Not Graded Chemistry Homework		Assigned and Graded Chemistry Homework		<i>d</i>	<i>t</i> ^a	<i>p</i>
	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)			
Matter	95.47	(15.05)	104.81	(13.81)	0.65	-1.85	.04*
Atoms	97.55	(15.01)	102.61	(15.02)	0.34	-0.97	.17 [†]
Naming	99.51	(13.72)	100.53	(16.70)	0.07	-0.19	.42 [†]
Reactions	100.30	(15.23)	99.69	(15.25)	0.04	0.12	.45 [†]

^aNegative *t* result is in the direction of lower scores for students' in the assigned but not graded chemistry homework group.

[†]*ns.* **p* < .05.

Table 3

Students With Average Chemistry Potential Who Were Given Teacher Assigned But Not Graded Chemistry Homework Compared to Students With Average Chemistry Potential Who Were Given Teacher Assigned and Graded Chemistry Homework 11th-Grade Chemistry Scores for Teacher Prepared 11th-Grade Criterion-Referenced Tests for Matter, Atoms, Naming, and Reactions

Measure	<i>Students With Average Chemistry Potential</i>		<i>d</i>	<i>t</i> ^a	<i>p</i>
	Assigned But Not Graded Chemistry Homework <i>M</i> (<i>SD</i>)	Assigned and Graded Chemistry Homework <i>M</i> (<i>SD</i>)			
Matter	94.76 (13.82)	106.70 (11.44)	0.95	-2.67	.006**
Atoms	98.36 (15.29)	102.40 (14.86)	0.27	-0.76	.23 [†]
Naming	98.97 (12.64)	102.63 (15.78)	0.26	-0.72	.24 [†]
Reactions	100.48 (12.79)	101.14 (16.15)	0.05	-0.13	.45 [†]

^aNegative *t* result is in the direction of lower scores for students' in the assigned but not graded chemistry homework group.

[†]*ns.* ***p* < .01.

Table 4

Students With Below Average Chemistry Potential Who Were Given Teacher Assigned But Not Graded Chemistry Homework Compared to Students With Below Average Chemistry Potential Who Were Given Teacher Assigned and Graded Chemistry Homework 11th-Grade Chemistry Scores for Teacher Prepared 11th-Grade Criterion-Referenced Tests for Matter, Atoms, Naming, and Reactions

<i>Students With Below Average Chemistry Potential</i>							
Measure	Assigned But Not Graded Chemistry Homework		Assigned and Graded Chemistry Homework		<i>d</i>	<i>t</i> ^a	<i>p</i>
	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)			
Matter	95.09	(15.62)	106.67	(11.52)	0.85	-2.34	.01**
Atoms	98.87	(14.94)	101.54	(15.52)	0.18	-0.50	.31 [†]
Naming	97.52	(16.57)	103.37	(12.36)	0.40	-1.11	.14 [†]
Reactions	97.78	(16.46)	103.01	(12.70)	0.36	-0.99	.17 [†]

^aNegative *t* result is in the direction of lower scores for students' in the assigned but not graded chemistry homework group.

[†]*ns.* ***p* = .01.

Table 5

All Students With Above Average, Average, and Below Average Chemistry Potential Who Were Given Teacher Assigned But Not Graded Chemistry Homework Compared to All Students With Above Average, Average, and Below Average Chemistry Potential Who Were Given Teacher Assigned and Graded Chemistry Homework 11th-Grade Chemistry Scores for Teacher Prepared 11th-Grade Criterion-Referenced Tests for Matter, Atoms, Naming, and Reactions

Measure	<i>All Students</i>		<i>d</i>	<i>t</i> ^a	<i>p</i>
	Assigned But Not Graded Chemistry Homework <i>M</i> (<i>SD</i>)	Assigned and Graded Chemistry Homework <i>M</i> (<i>SD</i>)			
Matter	95.12 (16.28)	105.29 (11.45)	0.73	-3.55	.0003***
Atoms	98.35 (15.03)	101.79 (14.91)	0.23	-1.14	.13 [†]
Naming	98.38 (15.44)	101.76 (14.48)	0.23	-1.12	.13 [†]
Reactions	99.00 (15.68)	101.09 (14.32)	0.14	-0.69	.25 [†]

^aNegative *t* result is in the direction of lower scores for students' in the assigned but not graded chemistry homework group.

[†]*ns.* ****p* < .001.

Table 6

Students With Above Average, Average, and Below Average Chemistry Potential Who Were Given Teacher Assigned But Not Graded Chemistry Homework Compared to Students With Above Average, Average, and Below Average Chemistry Potential Who Were Given Teacher Assigned and Graded Chemistry Homework 11th-Grade Chemistry Scores for District Prepared Chemistry Final Test

Chemistry Potential Levels	Assigned But Not Graded Chemistry Homework		Assigned and Graded Chemistry Homework		<i>d</i>	<i>t</i> ^a	<i>p</i>
	<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)			
Above Average	93.09	(13.02)	107.35	(13.69)	1.07	-3.07	.002**
Average	99.14	(10.43)	100.76	(18.42)	0.11	-0.30	.38 [†]
Below Average	95.23	(15.38)	106.48	(12.15)	0.82	-2.26	.02*
All Chemistry Potential Levels	96.37	(13.45)	103.94	(15.72)	0.52	-2.56	.006**

^aNegative *t* result is in the direction of lower scores for students' in the assigned but not graded chemistry homework group.

[†]*ns.* **p* < .05. ***p* < .01.

Table 7

Students With Above Average, Average, and Below Average Chemistry Potential Who Were Given Teacher Assigned But Not Graded Chemistry Homework Compared to Students With Above Average, Average, and Below Average Chemistry Potential Who Were Given Teacher Assigned and Graded Chemistry Homework 11th-Grade Physical Science Strand Scores for District Prepared Essential Learner Outcome Graduation Requirement Assessment

Chemistry Potential Levels	Assigned But Not Graded Chemistry Homework	Assigned and Graded Chemistry Homework	<i>d</i>	<i>t</i> ^a	<i>p</i>
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)			
Above Average	94.89 (13.61)	105.40 (15.05)	0.73	-2.11	.02*
Average	95.28 (15.09)	104.15 (13.98)	0.61	-1.73	.04*
Below Average	100.25 (13.75)	99.62 (17.21)	0.04	0.12	.45 [†]
All Chemistry Potential Levels	97.16 (13.88)	103.12 (15.63)	0.40	-2.00	.02*

^aNegative *t* result is in the direction of lower scores for students' in the assigned but not graded chemistry homework group.

[†]*ns.* **p* < .05.

Table 8

The Spearman Rank-Order Correlation Coefficient of Students With Above Average, Average, and Below Average Chemistry Potential Percentage of Completion of Teacher Assigned But Not Graded Chemistry Homework and Their Teacher Prepared 11th-Grade Criterion-Referenced Chemistry Assessment Scores

<i>All Students Not Graded Homework</i>							
Chemistry Potential	Chemistry Unit	Students' Completed Homework	Students' Chemistry Assessment	<i>df</i>	<i>r_s</i>	<i>r²</i>	<i>p</i>
		<i>average</i>	<i>average</i>				
Above	Matter	97.57	89.41				
Above	Atoms	85.10	84.15				
Above	Naming	78.89	84.06				
Above	Reactions	68.59	81.92				
Average	Matter	80.85	78.30				
Average	Atoms	58.30	69.43				
Average	Naming	48.81	67.47				
Average	Reactions	42.81	65.01				
Below	Matter	76.02	72.58				
Below	Atoms	52.76	67.39				
Below	Naming	42.75	62.32				
Below	Reactions	33.68	58.13				
				11	.97	95%	< .001

Note. This correlation coefficient indicates that there is a 95% coefficient of determination measure of strength of relationship between not completing, not graded chemistry homework and a corresponding drop in chemistry assessment scores for all students.

Table 9

The Spearman Rank-Order Correlation Coefficient of Students With Above Average, Average, and Below Average Chemistry Potential Percentage of Completion of Teacher Assigned and Graded Chemistry Homework and Their Teacher Prepared 11th-Grade Criterion-Referenced Chemistry Assessment Scores

<i>All Students Graded Homework</i>							
Chemistry Potential	Chemistry Unit	Students' Completed Homework	Students' Chemistry Assessment	<i>df</i>	<i>r_s</i>	<i>r²</i>	<i>p</i>
		<i>average</i>	<i>average</i>				
Above	Matter	91.94	93.66				
Above	Atoms	81.50	87.13				
Above	Naming	88.46	84.77				
Above	Reactions	84.20	81.31				
Average	Matter	85.63	86.53				
Average	Atoms	65.97	72.79				
Average	Naming	69.08	70.47				
Average	Reactions	65.66	65.76				
Below	Matter	80.31	83.93				
Below	Atoms	64.04	69.96				
Below	Naming	60.30	74.29				
Below	Reactions	51.72	64.57				
				11	.91	82%	< .001

Note. This correlation coefficient indicates that there is an 82% coefficient of determination measure of strength of relationship between not completing graded chemistry homework and a corresponding drop in chemistry assessment scores for all students.

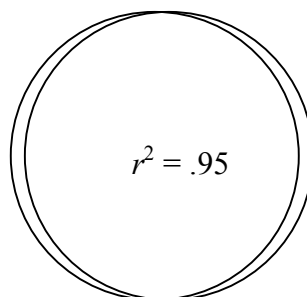


Figure 1. A 95% coefficient of determination measure of strength of relationship between not completing, not graded chemistry homework and a corresponding drop in chemistry assessment scores for all students.

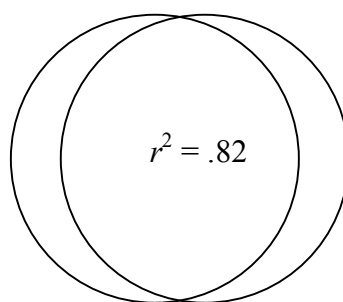


Figure 2. An 82% coefficient of determination measure of strength of relationship between not completing graded chemistry homework and a corresponding drop in chemistry assessment scores for all students.

CHAPTER FIVE

Conclusions and Discussion

The purpose of this study was to determine the impact of teacher assigned but not graded chemistry homework on the formative and summative chemistry assessment scores of 11th-grade students with above average, average, and below average chemistry potential compared to the formative and summative chemistry assessment scores of 11th-grade students with above average, average, and below average chemistry potential who completed teacher assigned and graded chemistry homework assignments.

The study analyzed 2005 posttest data to 2008 posttest data to determine student academic achievement outcomes across three academic levels, above average, average, and below average chemistry potential, and two teacher homework evaluation methods on teacher prepared 11th-grade chemistry assessments for matter, atoms, naming, and reactions, district prepared 11th-grade end of course final assessment, and district graduation requirement physical science strand 11th-grade science Essential Learner Outcome assessment.

All study achievement data related to each of the dependent variables were retrospective, archival, and routinely collected school information. Permission from the appropriate school research personnel was obtained before data were collected and analyzed.

Students who participated in this study were 11th-grade students enrolled in a chemistry course taught by the predetermined teacher in 2005 or 2008 and completed all four teacher-prepared unit assessments, the district-prepared assessment, and district

prepared physical science strand of the science ELO. The students were randomly placed through the registration process.

Conclusions

The results allow us to respond to the 14 research questions guiding the study.

Research Question #1

Overall, results indicated students with above average chemistry potential who were given teacher assigned and graded chemistry homework had higher scores for matter, atoms, and naming compared to students with above average chemistry potential who were given teacher assigned but not graded chemistry homework except for reactions which was greater for the assigned but not graded chemistry homework group. Comparing students' with above average chemistry potential end of 11th-grade teacher prepared criterion-referenced chemistry mean assessment scores with derived classroom performance scores helps put students' course achievement in perspective. A matter assessment, mean score of 95.47 for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 89.41 and an assessment grade of "B" while a matter assessment, mean score of 104.81 for students with above average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 93.66 and an assessment grade of "A". An atoms assessment, mean score of 97.55 for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 84.15 and an assessment grade of "C" while an atoms assessment, mean score of 102.61 for students with above average chemistry potential who were given teacher assigned and graded

chemistry homework is equivalent to a grade percentage of 87.12 and an assessment grade of “B”. A naming assessment, mean score of 99.51 for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 84.06 and an assessment grade of “C” while a naming assessment, mean score of 100.53 for students with above average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 84.77 and an assessment grade of “B”. A reactions assessment, mean score of 100.30 for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 81.91 and an assessment grade of “C” while a reactions assessment, mean score of 99.69 for students with above average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 81.32 and an assessment grade of “C”.

Finally, the higher teacher prepared 11th-grade criterion-referenced test scores for students with above average chemistry potential who were given teacher assigned and graded chemistry homework in matter (statistically different), atoms (not statistically different), and naming (not statistically different), represents a pattern of improvement that may reflect the impact of participation in a high school science classroom where the teacher assigns and grades homework as feedback to support student learning and improvement. Overall, the data supports continuation of teacher assigned and graded homework practices even though statistical equipoise was observed for atoms, naming, and reactions assessments.

Research Question #2

Overall, results indicated students with average chemistry potential who were given teacher assigned and graded chemistry homework had higher scores for all four assessments matter, atoms, naming, and reactions compared to students with average chemistry potential who were given teacher assigned but not graded chemistry homework. Comparing students' with average chemistry potential end of 11th-grade teacher prepared criterion-referenced chemistry mean assessment scores with derived classroom performance scores helps put students' course achievement in perspective. A matter assessment, mean score of 94.76 for students with average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 79.34 and an assessment grade of "C" while a matter assessment, mean score of 106.70 for students with average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 86.92 and an assessment grade of "B". An atoms assessment, mean score of 98.36 for students with average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 69.86 and an assessment grade of "D" while an atoms assessment, mean score of 102.40 for students with average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 73.21 and an assessment grade of "D". A naming assessment, mean score of 98.97 for students with average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 68.38 and an assessment grade of "F" while a naming assessment, mean score of 102.63 for students with average chemistry potential who were given

teacher assigned and graded chemistry homework is equivalent to a grade percentage of 71.66 and an assessment grade of “D”. A reactions assessment, mean score of 100.48 for students with average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 65.94 and an assessment grade of “F” while a reactions assessment, mean score of 101.14 for students with average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 66.67 and an assessment grade of “F”.

Finally, the higher teacher prepared 11th-grade criterion-referenced test scores for students with average chemistry potential who were given teacher assigned and graded chemistry homework in matter (statistically different), atoms (not statistically different), naming (not statistically different), and reactions (not statistically different) represents a pattern of improvement that may reflect the impact of participation in a high school science classroom where the teacher assigns and grades homework as feedback to support student learning and improvement. However, for students with average chemistry potential it must be observed that whether assigned homework is graded or not chemistry coursework may improve assessment scores but not necessarily to a point of raising course grades to the level of average or better. Overall, despite this observation, continuation of teacher assigned and graded homework practices seems warranted for these students who based on the research results are struggling to achieve even average grades.

Research Question #3

Overall, results indicated students with below average chemistry potential who were given teacher assigned and graded chemistry homework had higher scores for all

four assessments matter, atoms, naming, and reactions compared to students with below average chemistry potential who were given teacher assigned but not graded chemistry homework. Comparing students' with below average chemistry potential end of 11th-grade teacher prepared criterion-referenced chemistry mean assessment scores with derived classroom performance scores helps put students' course achievement in perspective. A matter assessment, mean score of 95.09 for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 72.58 and an assessment grade of "D" while a matter assessment, mean score of 106.67 for students with below average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 83.93 and an assessment grade of "C". An atoms assessment, mean score of 98.87 for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 67.39 and an assessment grade of "F" while an atoms assessment, mean score of 101.54 for students with below average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 69.96 and an assessment grade of "D". A naming assessment, mean score of 97.52 for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 62.32 and an assessment grade of "F" while a naming assessment, mean score of 103.37 for students with below average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 67.54 and an assessment grade of "F". A reactions assessment, mean score of 97.78 for students with below average chemistry

potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 58.14 and an assessment grade of “F” while a reactions assessment, mean score of 103.01 for students with below average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 64.58 and an assessment grade of “F”.

Finally, the higher teacher prepared 11th-grade criterion-referenced assessment scores for students with below average chemistry potential who were given teacher assigned and graded chemistry homework in matter (statistically different), atoms (not statistically different), naming (not statistically different), and reactions (not statistically different) represents a pattern of improvement that may reflect the impact of participation in a high school science classroom where the teacher assigns and grades homework as feedback to support student learning and improvement. However, for students with below average chemistry potential it must be observed that whether assigned homework is graded or not chemistry coursework may improve assessment scores but not necessarily to a point of raising course grades to even a passing level. Overall, despite this observation, continuation of teacher assigned and graded homework practices seems warranted for these students who based on the research results are struggling to achieve even passing grades.

Research Question #4

Overall, results indicated all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework had higher scores for all four assessments matter, atoms, naming, and reactions compared to all students with above average, average, and below average

chemistry potential who were given teacher assigned but not graded chemistry homework. Comparing all students' with above average, average, and below average chemistry potential end of 11th-grade teacher prepared criterion-referenced chemistry mean assessment scores with derived classroom performance scores helps put students' course achievement in perspective. A matter assessment, mean score of 95.12 for all students with above average, average, and below average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 79.87 and an assessment grade of "C" while a matter assessment, mean score of 105.29 for all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 88.18 and an assessment grade of "B". An atoms assessment, mean score of 98.35 for all students with above average, average, and below average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 83.58 and an assessment grade of "C" while an atoms assessment, mean score of 101.79 for all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 86.83 and an assessment grade of "B". A naming assessment, mean score of 98.38 for all students with above average, average, and below average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 71.08 and an assessment grade of "D" while a naming assessment, mean score of 101.76 for all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent

to a grade percentage of 74.46 and an assessment grade of “D”. A reactions assessment, mean score of 99.00 for all students with above average, average, and below average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 68.09 and an assessment grade of “F” while a reactions assessment, mean score of 101.09 for all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 70.70 and an assessment grade of “D”.

Finally, the higher teacher prepared 11th-grade criterion-referenced test scores for all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework in matter (statistically different), atoms (not statistically different), naming (not statistically different), and reactions (not statistically different) represents a pattern of improvement that may reflect the impact of participation in a high school science classroom where the teacher assigns and grades homework as feedback to support student learning and improvement. Overall, continuation of teacher assigned and graded homework practices, seems warranted for all students regardless of their chemistry potential.

Research Question #5

Overall, results indicated students with above average chemistry potential who were given teacher assigned and graded chemistry homework had a higher score for the district prepared final chemistry assessment compared to students with above average chemistry potential who were given teacher assigned but not graded chemistry homework. Comparing students' with above average chemistry potential district prepared

final chemistry assessment scores with derived classroom performance scores helps put students' course achievement in perspective. A district prepared final chemistry assessment, mean score of 93.09 for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 75.39 and an assessment grade of "D" while a district prepared final chemistry assessment, mean score of 107.35 for students with above average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 87.79 and an assessment grade of "B".

Finally, the higher district prepared final chemistry assessment score (statistically different) for students with above average chemistry potential who were given teacher assigned and graded chemistry homework represents a pattern of improvement that may reflect the impact of participation in a high school science classroom where the teacher assigns and grades homework as feedback to support student learning and improvement. Overall, the data supports continuation of teacher assigned and graded homework practices.

Research Question #6

Overall, results indicated students with average chemistry potential who were given teacher assigned and graded chemistry homework had a higher score for the district prepared final chemistry assessment compared to students with average chemistry potential who were given teacher assigned but not graded chemistry homework. Comparing students' with average chemistry potential district prepared final chemistry assessment scores with derived classroom performance scores helps put students' course achievement in perspective. A district prepared final chemistry assessment, mean score

of 99.14 for students with average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 61.77 and an assessment grade of “F” while a district prepared final chemistry assessment, mean score of 100.76 for students with average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 63.46 and an assessment grade of “F”.

Finally, the higher district prepared final chemistry assessment score (not statistically different) for students with average chemistry potential who were given teacher assigned and graded chemistry homework represents a pattern of improvement that may reflect the impact of participation in a high school science classroom where the teacher assigns and grades homework as feedback to support student learning and improvement. However, for students with average chemistry potential it must be observed that whether assigned homework is graded or not chemistry coursework may improve assessment scores but not necessarily to a point of raising course grades to the level of even passing. Overall, despite this observation, continuation of teacher assigned and graded homework practices seems warranted for these students who based on the research results are struggling to achieve even average grades.

Research Question #7

Overall, results indicated students with below average chemistry potential who were given teacher assigned and graded chemistry homework had a higher score for the district prepared final chemistry assessment compared to students with below average chemistry potential who were given teacher assigned but not graded chemistry homework. Comparing students' with below average chemistry potential district

prepared final chemistry assessment scores with derived classroom performance scores helps put students' course achievement in perspective. A district prepared final chemistry assessment, mean score of 95.23 for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 52.28 and an assessment grade of "F" while a district prepared final chemistry assessment, mean score of 106.48 for students with below average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 63.68 and an assessment grade of "F".

Finally, the higher district prepared final chemistry assessment score (statistically different) for students with below average chemistry potential who were given teacher assigned and graded chemistry homework represents a pattern of improvement that may reflect the impact of participation in a high school science classroom where the teacher assigns and grades homework as feedback to support student learning and improvement. However, for students with below average chemistry potential it must be observed that whether assigned homework is graded or not chemistry coursework may improve assessment scores but not necessarily to a point of raising course grades to the level of even passing. Overall, despite this observation, continuation of teacher assigned and graded homework practices seems warranted for these students who based on the research results are struggling to achieve even passing grades.

Research Question #8

Overall, results indicated all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework had a higher score for the district prepared final chemistry assessment

compared to all students with above average, average, and below average chemistry potential who were given teacher assigned but not graded chemistry homework. Comparing all students' with above average, average, and below average chemistry potential district prepared final chemistry assessment scores with derived classroom performance scores helps put students' course achievement in perspective. A district prepared final chemistry assessment, mean score of 96.37 for all students with above average, average, and below average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a grade percentage of 62.78 and an assessment grade of "F" while a district prepared final chemistry assessment, mean score of 103.94 for all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to a grade percentage of 71.81 and an assessment grade of "D".

Finally, the higher district prepared final chemistry assessment score (statistically different) for all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework represents a pattern of improvement that may reflect the impact of participation in a high school science classroom where the teacher assigns and grades homework as feedback to support student learning and improvement. However, for all students with above average, average, and below average chemistry potential it must be observed that whether assigned homework is graded or not chemistry coursework may improve assessment scores but not necessarily to a point of raising course grades to the level of average or better. Overall, despite this observation, continuation of teacher assigned and graded homework practices seems warranted for these students.

Research Question #9

Overall, results indicated students with above average chemistry potential who were given teacher assigned and graded chemistry homework had a higher score for the physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment compared to students with above average chemistry potential who were given teacher assigned but not graded chemistry homework. Comparing students' with above average chemistry potential physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment scores with derived classroom performance scores helps put students' course achievement in perspective. A physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment, mean score of 94.89 for students with above average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a physical science strand score of 10.88 (out of 18) and proficiency level of proficient while a physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment, mean score of 105.40 for students with above average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to 12.94 (out of 17) and proficiency level of beyond proficient.

Finally, the higher physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment score (statistically different) for students with above average chemistry potential who were given teacher assigned and graded chemistry homework represents a pattern of improvement that may reflect the impact of participation in a high school science classroom where the teacher assigns and

grades homework as feedback to support student learning and improvement. Overall, the data supports continuation of teacher assigned and graded homework practices.

Research Question #10

Overall, results indicated students with average chemistry potential who were given teacher assigned and graded chemistry homework had a higher score for the physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment compared to students with average chemistry potential who were given teacher assigned but not graded chemistry homework. Comparing students' with average chemistry potential physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment scores with derived classroom performance scores helps put students' course achievement in perspective. A physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment, mean score of 95.28 for students with average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a physical science strand score of 9.00 (out of 18) and proficiency level of barely proficient while a physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment, mean score of 104.15 for students with average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to 11.12 (out of 17) and proficiency level of beyond proficient.

Finally, the higher physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment score (statistically different) for students with average chemistry potential who were given teacher assigned and graded chemistry homework represents a pattern of improvement that may reflect the impact of

participation in a high school science classroom where the teacher assigns and grades homework as feedback to support student learning and improvement. Overall, the data supports continuation of teacher assigned and graded homework practices.

Research Question #11

Overall, results indicated students with below average chemistry potential who were given teacher assigned and graded chemistry homework had a higher score for the physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment compared to students with below average chemistry potential who were given teacher assigned but not graded chemistry homework. Comparing students' with below average chemistry potential physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment scores with derived classroom performance scores helps put students' course achievement in perspective. A physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment, mean score of 100.25 for students with below average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a physical science strand score of 9.74 (out of 18) and proficiency level of barely proficient while a physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment, mean score of 99.62 for students with below average chemistry potential who were given teacher assigned and graded chemistry homework is equivalent to 10.07 (out of 17) and proficiency level of proficient.

Finally, the higher physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment score (not statistically different) for

students with below average chemistry potential who were given teacher assigned and graded chemistry homework represents a pattern of improvement that may reflect the impact of participation in a high school science classroom where the teacher assigns and grades homework as feedback to support student learning and improvement. Overall, the data supports continuation of teacher assigned and graded homework practices.

Research Question #12

Overall, results indicated all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework had a higher score for the physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment compared to all students with above average, average, and below average chemistry potential who were given teacher assigned but not graded chemistry homework. Comparing all students' with above average, average, and below average chemistry potential physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment scores with derived classroom performance scores helps put students' course achievement in perspective. A physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment, mean score of 97.16 for all students with above average, average, and below average chemistry potential who were given teacher assigned but not graded chemistry homework is equivalent to a physical science strand score of 9.90 (out of 18) and proficiency level of barely proficient while a physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment, mean score of 103.12 for all students with above average, average, and below average chemistry potential who were given teacher assigned and

graded chemistry homework is equivalent to 11.43 (out of 17) and proficiency level of beyond proficient.

Finally, the higher physical science strand of the district prepared Essential Learner Outcome graduation requirement assessment score (statistically different) for all students with above average, average, and below average chemistry potential who were given teacher assigned and graded chemistry homework represents a pattern of improvement that may reflect the impact of participation in a high school science classroom where the teacher assigns and grades homework as feedback to support student learning and improvement. Overall, the data supports continuation of teacher assigned and graded homework practices.

Research Question #13

Based on the substantial relationship ($r > .90$) observed between not graded chemistry homework averages and graded chemistry assessment averages where $r = .9735$ and a probability level of $< .001$ the null hypothesis of no relationship between not completing, not graded homework and a corresponding drop in chemistry assessment scores for all students is rejected. Furthermore, the Spearman rank order coefficient of correlation squared $r^2 = .95$ indicates a 95% coefficient of determination (see *Figure 1*) or shared variance between the two sets of data indicating that there is a 95% rank order relationship between not completing, not graded homework and a corresponding drop in chemistry assessment scores for all students.

Finally, taken all together it may be said that based on the substantial relationship observed between not completing, not graded homework and a corresponding drop in chemistry assessment scores for all students it may be assumed that students who

complete more not graded homework have a 95% probability of improving their chemistry assessment scores regardless of their chemistry potential.

Research Question #14

Based on the substantial relationship ($r > .90$) observed between graded chemistry homework averages and graded chemistry assessment averages where $r = .9073$ and a probability level of $< .001$ the null hypothesis of no relationship between not completing, graded homework and a corresponding drop in chemistry assessment scores for all students is rejected. Furthermore, the Spearman rank order coefficient of correlation squared $r^2 = .82$ indicates an 82% coefficient of determination (see *Figure 2*) or shared variance between the two sets of data indicating that there is a 82% rank order relationship between not completing, graded homework and a corresponding drop in chemistry assessment scores for all students.

Finally, taken all together it may be said that based on the substantial relationship observed between not completing, graded homework and a corresponding drop in chemistry assessment scores for all students it may be assumed that students who complete more graded homework have an 82% probability of improving their chemistry assessment scores regardless of their chemistry potential.

Discussion

The study conclusions suggest that grading for learning (O'Connor, 2002) may be wholly compatible with rigorous difficult scientific high school subject matter but the relationship between student ability, motivation, and course requirements, such as completing homework, may be as complex and difficult to untangle as a stoichiometric conversion.

Student motivation and chemistry potential. Students vary in both motivation and potential. Just as every student does not possess the ability to be a star quarterback, not every student has the ability to be an “A” chemistry student. The student’s potential contributes to their overall grade but should not hinder the student from learning enough information to pass the course. A student’s motivation or lack thereof also plays a major role in the student’s ability to do well in chemistry. The combination of potential and motivation is a key ingredient in the recipe to succeed. A student that lacks a lot of natural potential, yet is highly motivated to do well, will succeed through hard work. On the flipside an unmotivated student with a lot of natural potential may not succeed as their lack of effort limits their potential for success. Motivation to succeed helps level the playing field between students with varying chemistry potential. Whether the student is interested in chemistry or not, they must be motivated and engaged in order to be successful in this difficult core science course of study (Walczak & Walczak, 2009).

For some students, the big picture of graduation and future goals is enough to motivate them into successfully completing chemistry with high scores. Just as athletes understand that practicing everyday is required to perform well in the big game, great scholars understand that studying everyday is required to perform well on the big test. For intrinsically motivated students completing course assignments and learning the course content is its own reward (Ratelle et al., 2007). For extrinsically motivated students additional motivation such as points attached to an assignment may be necessary. Students who are extrinsically motivated do not see the importance of completing homework and studying every day in order to learn for learning’s sake or do well in the future (Ratelle et al., 2007). However, unmotivated students do not respond to

either intrinsic or extrinsic rewards (Ratelle et al., 2007). In this study homework points led to more students completing their homework, leading to higher assessment scores, and aiding in long term retention as reflected in higher district final and ELO scores.

The relationship between completing homework and earning higher assessment scores helps shine a light on how student motivation affects student academic outcomes. A true measure of student motivation is unobtainable, but the completion of homework is an indicator of the student's study skills and in turn an indicator of their motivation. A student that is motivated to do well on the homework is generally motivated to do well in the class (Hahn & Polik, 2004).

In general, it is seen that students with higher potential outscore those students with less potential. However, within the bands of ability level, the motivation factor is seen. Students that completed more homework outscore similar students that completed less homework. Level of motivation is also apparent at the time of the chemistry final. Students in the upper tier and lower tier are most heavily affected by the final as there is a finite line separating them from the grade they desire and a grade they might be forced to live with. The students with "As" need to do well enough on the final to keep their "A" while the students with "Ds" and high "Fs" need to do well enough to pass the class. Those students in the middle range of chemistry potential are less affected by the final as they are in a grey area of "Bs" and "Cs" in which it would be nice to get a "B" but not detrimental to earn a "C."

While a student with below average chemistry potential may not have the ability to earn an "A," motivation to complete homework in an attempt to better understand the difficult concepts associated with chemistry does have a positive impact on their overall

understanding and assessment scores associated with chemistry. Likewise, a student with above average chemistry potential may not be likely to fail, their motivation to complete homework helps ensure they master the difficult concepts in order to understand chemistry and earn their desired grade. Awarding points for completed homework allows the teacher to encourage all students to master and retain important and focused chemistry content that must be retained to successfully complete the required district assessments.

Differentiation of instruction and inclusion. Placing students with greatly varying chemistry potential in the same classroom presents the teacher with important instructional challenges. The teacher must reteach and review important concepts for students with below average chemistry potential while at the same time move quickly enough through the course content to inspire and challenge students with greater chemistry potential (Differentiating Instruction, 2010). Teaching the subject matter using various methods allows students with different learning styles to understand the material.

In order to allow above average students the opportunity to learn as much as possible independent course challenge and extension opportunities--beyond the course requirements--are made available when the teacher must spend additional time reviewing and reteaching course content for other students in the classroom. In order to ensure fairness in grading, the challenge or extension assignment offered to students in the class with the greatest chemistry potential may take the place of other assigned coursework.

For all students, regardless of their chemistry potential, lowering science standards is not an option (Gill & Schlossman, 2004). All students need to have a high level of understanding of biological, chemical, and physical sciences. The national, state,

and district science standards continue to evolve and become more complex. In order to guarantee that teachers are teaching the required material, assessment scores are becoming increasingly important. It is necessary for the teacher to be able to teach all students at all academic potentials all the required information. Making sure that all students perform to the best of their ability is a very challenging task especially when the task involves understanding the complex information associated with chemistry (Gibbs, 2005).

One way to diminish the confusion associated with placing all students with varying potential in the same room is to offer an honors chemistry course at the high school level. Allowing the above average chemistry students to be placed in a separate class would allow them the opportunity to explore and master more challenging chemistry coursework. Mastering more difficult chemistry concepts would better prepare these students to move on to even more difficult chemistry concepts like those seen in Advanced Placement and college chemistry courses. Students partaking in more rigorous, honors level high school chemistry classes perform better at the college level because the transition into the complex and difficult course of college chemistry is easier for the student to make (Lamb, 1991). It is believed that successful transition is a function of higher expectations and not simply exposure to a more difficult subject matter (Lamb, 1991). Ensuring that these top students are prepared to move onto more advanced university chemistry coursework is the best way to prepare tomorrow's scientists (Barton, 2009).

Final thought. Never before has understanding and mastering high school chemistry knowledge and application been more important for tomorrow's experimental

scientists, physicians, physicists, and engineers--literally those high school students who will go on to universities and occupations that will shape our future, indeed, our very existence. Chemistry coursework must remain rigorous, and given this study's findings chemistry teachers must be empowered to give homework--graded or not graded--when they deem it is appropriate based on the difficulty of the subject matter and the need for student work outside of the classroom informed by the eight practices of grading for learning (O'Connor, 2002).

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