2015

Experiences Teaching Stoichiometry to Students in Grades 10 and 11

Cynthia Denise Bridges
Walden University

Walden University

COLLEGE OF EDUCATION

This is to certify that the doctoral study by

Cynthia Denise Bridges

has been found to be complete and satisfactory in all respects,
and that any and all revisions required by
the review committee have been made.

Review Committee
Dr. Heather Miller, Committee Chairperson, Education Faculty
Dr. Tom Cavanagh, Committee Member, Education Faculty
Dr. David Bail, University Reviewer, Education Faculty

Chief Academic Officer

Eric Riedel, Ph.D.

Walden University
2015

Abstract

Experiences Teaching Stoichiometry to Students in Grades 10 and 11

by

Cynthia Denise Bridges

MEd, University of Massachusetts, 1989

BS, Clark Atlanta University, 1988

Doctoral Study Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Education

Walden University

February 2015

Abstract

Many students have problems learning stoichiometry, a complex mathematical chemistry concept used to determine how much product will be produced or formed from a given quantity of reactants. The problem addressed in this study was teachers' lack of understanding of how to teach stoichiometry in a Midwestern urban school district. The conceptual framework of the study was based upon constructivist theory. A qualitative narrative approach was used to obtain the perceptions of 5 high school chemistry instructors related to their experiences, successful or unsuccessful, in teaching stoichiometry to students in Grades 10 and 11. Data were gathered through face-to-face interviews, which were analyzed via an inductive approach to reveal 6 themes: a difficult subject to teach, presentation of stoichiometry, relevancy, students' reactions, barriers, and gender differences. Findings suggested the need for teachers to be knowledgeable, creative, and resourceful in their subject areas to help their students to learn stoichiometry. Findings also revealed the need for teachers to adapt their instructional strategies and modes of delivery to reflect their students' individual learning styles. Understanding how the participating teachers explained stoichiometry to their students might help other chemistry teachers to examine and adapt their own instructional styles and delivery methods of the concept. This understanding might, in term, help to improve student achievement in stoichiometry in particular and chemistry in general.

Experiences Teaching Stoichiometry to Students in Grades 10 and 11

by

Cynthia Denise Bridges

MEd, University of Massachusetts, 1989

BS, Clark Atlanta University, 1988

Doctoral Study Submitted in Partial Fulfillment

of the Requirements for the Degree of

Doctor of Education

Walden University

February 2015

Acknowledgments

First, I would like to give honor to God for keeping and helping me through this process. Thanks to my mother for her continual prayers and support. I thank my sons, BJ and Brandon, for your patience and help. I will forever be grateful to you because you were the ones who knew firsthand what Mommy was going through. You guys are the greatest. I love you so much. Thank you to Mr. Gordon for allowing me to work after hours. Thanks to my Science Quiz Bowl students for understanding when I had to write. Thanks to the teachers who participated in this study and their principals for giving their permission. Thanks to my family for not throwing me out of the family when I could not participate in activities because of homework. Thanks to my friends for your encouraging words. Thanks to Dr. Heather Miller, doctoral chair, and Dr. Tom Cavanagh, committee member, for all of your help and guidance.

Table of Contents

List of Tables

Section 1: Introduction to the Study

Chemistry is one of the most challenging courses in the high school science sequence (Uce, 2009). In the chemistry curriculum, students must master the important concept of stoichiometry, a mathematical chemistry concept that is used to determine how much product will be produced or formed from a given quantity of reactants (Zumdahl, 2002). Reactants are substances that are mixed to form another product (e.g., sodium hydroxide and hydrochloric acid are mixed to produce sodium chloride and water). Stoichiometry is the foundation of chemistry, so if students cannot understand stoichiometry, they cannot understand chemistry (Paideya, 2010).

Students demonstrate poor achievement in and their lack of understanding of stoichiometry in several ways: poor grades on tests and quizzes, missing or incomplete assignments, lack of class participation, poor attendance, and reduced time on task. Researchers have found that students learn best when instructional strategies include the use of multiple intelligences (MIs) and individual learning styles (Holliday & Said, 2008; Romanelli, Bird, & Ryan, 2009). Many chemistry teachers tend to promote kinetic learning styles by using hands-on practical exercises and problem-solving strategies (Oskay, Erdem, Akkoyunlu, & Ytlmaz, 2010; Pedretti, 2010).

Students with different learning styles use preferred study strategies and MIs to learn (Dahsah & Kruatong, 2010; Eaves, 2009). Students should understand different learning styles, as well as the strengths of their personal learning styles (Boström, 2012; Oskay et al., 2010). It is informative for teachers to be aware of students' learning styles (Entwistle & Newble, 1986; Wehrwein, Lujan, & DiCarlo, 2007). No single teaching method is appropriate for all learning styles and a mismatch between teaching methods and students' learning styles can be detrimental to the learning process (Boström, 2012). Specific to this study, when chemistry teachers match their instructional styles to the learning styles of their students, it improves the learning process (Watters & Watters, 2007).

The shortage of qualified science teachers is a major concern facing the U.S. education system. Because of this shortage, many unqualified teachers who are not certified are teaching science (Center for Teaching Quality, 2006). In some instances, districts must lower their qualifications to place teachers in the science classroom (Darling-Hammond & Sykes, 2003; Jacob, 2007). Chemistry and physics are the curriculum areas with the largest shortage of teachers; only 35% of chemistry or physics classrooms have teachers who are considered highly qualified (Darling-Hammond & Berry, 2006).

Students need qualified chemistry teachers. The United States is facing not only a shortage of students majoring in science-related fields but also a deficit of students who are actually achieving in science (Maltese & Tai, 2011). Over the next 10 years, President Obama (2009) wants the scientific literacy of American students moved to the forefront in science education in an effort to improve student achievement in science and math. In the United States, education reform in mathematics and science from Kindergarten to Grade 12 has been at the center of the national debate, with many efforts focusing on improving these two curricula (Bybee & Stage, 2005; President's Council of Advising on Science and Technology, 2010).

Scientific literacy refers to understanding science and the ways in which it can be applied to society (Dani, Wan, & Henning, 2010). According to Oblinger (2006), students need scientific literacy to understand such complex issues as climate change, oil spills, and influenza epidemics. Scientific literacy guides decisions about education and community participation (Holbrook, 2009; Yuenyong & Narjaikaew, 2009). Although science, technology, and math education are important to the future of the United States and other countries across the globe, Grade 12 students in the United States have scored below the international average in science and mathematics, and they continue to struggle (Armario, 2011; Viadero, 2005). According to the National Assessment of Educational Progress (NAEP, as cited in Hechinger, 2011), 21% of students in Grade 12 are performing at or above proficiency in science and only 1% are performing at the advanced level. U.S. students have been regarded as minority participants in science-related fields (Bybee & Kennedy, 2005). Various sources have cited a report from the National Academy of Sciences (NAS) that any leadership advantages that the United States had in the fields of math and science are declining (Loucks-Horsley & Matsumoto, 1999; President's Council of Advising on Science and Technology, 2010; Stiles, Mundry, Hewson, Loucks-Horsley, & Love, 2009).

Educators in the United States need to encourage more students to major in math and science (Cordero, Porter, Israel, & Brown, 2010). A shortage of 70,000 engineers had been predicted to occur by 2010 (Kekelis & Gomes, 2009). The shortage of scientists and engineers has contributed to the shortfall in scientific inquiry and discovery (Cordero et al., 2010; Kekelis & Gomes, 2009). Because of the shortage of U.S. students majoring in science and technology, the country is in danger of losing its economic status in the 21st century (Guiso, Monte, Sapienza, & Zingales, 2008; Petrilli & Scull, 2011).

Problem Statement

The problem addressed in this study was that in traditional science classes, chemistry teachers tend to ignore students' individual learning styles and do not consider using MIs as part of their instructional strategies. These factors contribute to students' poor understanding of and underachievement in chemistry, particularly in regard to the concept of stoichiometry (J. Cross, 2007; Salamah & Schwartz, 2007). Chemistry students are frustrated and exhibit a poor attitude when they do not understand important concepts.

The problem is evident in low scores on tests and quizzes, missing and incomplete assignments, lack of student participation, low self-esteem, reduced time on task, and minimal student performance (N. Patel, personal communication, January 17, 2006). Many students develop negative attitudes toward chemistry once the concept of stoichiometry is introduced (E. Polk, personal communication, September 15, 2009). The failure to see the connection between chemistry and their everyday lives affects their desire to learn chemistry (Dahsah & Kruatong, 2010).

Some of the teachers who participated in this study gave me permission to use their names in the personal communications. The teachers in the study were identified by the numeric identifiers that I gave to them to protect their identities. Chemistry teachers working with me in the same urban school in the Midwestern United States have expressed concerns about the attitudes of their students (R. Johnson, personal communication, September 15, 2009; E. Polk, personal communication, September 15, 2009). In addition, because of declining test performance and unsatisfactory work on assignments, students are earning lower grades in their chemistry classes. The science teachers have observed that the students are not putting in the effort to be successful in chemistry (M. Fidler, personal communication, January 22, 2010). Students are not motivated because they believe that learning chemistry is too difficult and takes too much time. Many students do only what is necessary to pass the course (A. Artist, personal communication, March 13, 2009; J. Cooper, personal communication, March 13, 2009).

The chemistry teachers with whom I work are concerned that the lack of student motivation and the underachievement on assignments and assessments after stoichiometry is introduced will eventually impact the standardized test scores or will discourage students from considering science as a field of study at the next level (R. Johnson, personal communication, September 15, 2009). New approaches to teaching science are needed (Ozdemir, Guneysu, & Tekkaya, 2006). The narratives of the five high school chemistry teachers about their classroom experiences might provide other teachers with insight into ways to help students to learn stoichiometry.

During my tenure in the urban Midwestern school district where I teach, it has become clear to me that students are not doing as well as they should in chemistry. Initially, I wondered when they began to have difficulty learning the chemistry curriculum. I questioned my teaching style and the possible lack of student preparation for chemistry. I was genuinely concerned and confused. After careful observation of my students, I began to notice the point at which students lost focus, their understanding of concepts diminished, and their grades began to drop. I started paying attention to identify the problem. After my analysis, I found that despite acceptable performance on assignments and assessments indicating that the students had mastered the individual concepts of writing a compound; writing a balanced equation; and comprehending the concept of a mole, (i.e., unit of measurement used in chemistry to express amounts of chemical substances; Bureau international des poids et mésures, n.d.), when they had to put these concepts together, they could not grasp the concept of stoichiometry, which is the integration of the three concepts. Students were not applying the concepts, synthesizing the information, and solving problems in ways that could help them to understand stoichiometry.

After making this discovery, I determined that other chemistry teachers at my school were having the same problems. I thought that if we, in the context of a school designed for gifted and academically talented students, were having similar difficulties, I wondered what other high school chemistry teachers in the district were experiencing when teaching stoichiometry. I began to contemplate conducting a study to gain the insights of high school chemistry teachers about their own experiences in trying to help students to learn stoichiometry and experience success in what is considered to a difficult course in the science curriculum.

Research Question

In alignment with the research problem and purpose, I posed the following research question: What are the stories of chemistry teachers in an urban Midwestern U.S. school district about their experiences teaching the concept stoichiometry? One broad open-ended research question helped me to focus the study and remain open to what could emerge from the data (Bogdan & Biklen, 2007). As the data for any study are collected and analyzed, research questions can be refined and modified, and additional questions can be posed (Otero & Harlow, 2009; Stake, 1995; Wener & Woodgate, 2013).

Nature of the Study

I followed a narrative inquiry design to conduct this qualitative study to investigate the experiences of five chemistry teachers related to teaching the concept of stoichiometry in an urban Midwestern U.S. school district. The rationale for using a qualitative study was to understand the chemistry teachers' experiences from their perspectives. According to Creswell (2013), qualitative research is an exploratory method in which learning comes from the participants. Narrative research involves stories being told by the participants to the researcher (Creswell, 2013). Narrative analysis is an interpretive process.

The participants were five teachers of Grade 10 and 11 chemistry classes in an urban Midwestern U.S. school district. Each participant came from a school with unique characteristics. Teacher 1 was from an examination high school with a population of 1,050 students. Teacher 2 was from an all-boys school with a population of 230 students. Teacher 3 was from an application high school with a population of 182 students. Teacher 4 was from an alternative high school with a population of 549 students. Teacher 5 was from an all-girls school with a population of 618 students.

In qualitative research, interviewing is the primary method of data collection (Bloomberg & Volpe, 2008; Creswell, 2003). In the interview process, the participants have the opportunity to discuss their experiences of the problem under investigation (Stake, 1995). In education, conducting face-to-face semistructured interviews is the most common way to collect data (Coleman & Briggs, 2005). I asked five high school chemistry teachers about their experiences teaching the concept of stoichiometry to students in Grades 10 and 11 (see Appendix A). After completing the interviews, I transcribed the responses and then engaged in member checking. Following the member checking, I coded the data and analyzed them for patterns and themes. More details of the interviewing process are in Section 3.

Purpose

The purpose of this narrative study was to obtain the stories of five high school chemistry teachers about their experiences related to teaching the concept of stoichiometry to students in Grades 10 and 11. I obtained the data by conducting a private interview with each teacher. I will use the chemistry teachers’ experiences to help other chemistry teachers to improve students’ understanding of the concepts associated with stoichiometry.

Conceptual Framework

The conceptual framework of the study was based upon constructivist theory, particularly in regard to the constructivist paradigm for conducting research and constructivist pedagogy. Past researchers have focused on student learning of stoichiometry from the students’ point of view rather than from a theoretical framework introduced by the teacher (Agung & Schwartz, 2007; Dahsah & Coll, 2007). However, the stance taken in the paradigm used in the conceptual framework was constructivist theory, with the focus on the teachers' narrations of their experiences teaching the concept of stoichiometry.

Researchers can use constructivist theory to analyze the qualitative data collected from the interviews. Constructivism is a view of knowing or understanding. Analyzing the transcriptions of the interview responses helped me to understand and construct the best methods to teach the concept of stoichiometry. Using the constructivist approach allowed me to analyze the narratives initially by individual interview and then across interviews to create themes and identify patterns in the data. The voices of the teachers were the basis for constructing the findings.

The theory is based upon the notion that constructivism can help to explain how people learn (Taskin-Can, 2011). In this study, constructivism refers to the ability of the students to develop new learning (i.e., an understanding of stoichiometry) based upon previous knowledge (i.e., writing a compound, writing a balanced equation, and comprehending the concept of a mole).

Definitions

Chemistry: A branch of science dealing with the structure, composition, properties, and reactive characteristics of substances, especially at the atomic and molecular levels (Zumdahl, 2002).

Intelligence: The ability to solve problems or fashion products that are valued in one or more cultural or community settings (Gardner, 1993).

Learning style: "The way students begin to concentrate on, process, internalize, and remember new difficult academic information and is comprised of both biological and developmental characteristics that make the identical instructional environments, methods, and resources effective for some learners and ineffective for others" (Dollar, 2001, p. 1).

Polyatomic ions: Many atoms joined together with a charge (Herron et al., 1996).

Stoichiometry: A branch of chemistry concerned with measuring the proportions of elements that combine during chemical reactions (Myers, Oldham, & Tocci, 2004).

Assumptions, Scope, Delimitations, and Limitations

Assumptions

The first assumption of this study was that the participating teachers would have expertise in stoichiometry and would be able to discuss the concept thoroughly. The second assumption was that the teachers would provide honest and accurate responses to the interview questions.

Scope

I conducted this narrative study to obtain the experiences of high school chemistry teachers of stoichiometry who were working in five high schools in an urban Midwestern U.S. school district. I interviewed only teachers of Grade 10 and Grade 11 chemistry classes because those are the grades when chemistry is taught in this school district.

Delimitations

I collected data from a select group of high school chemistry teachers (Grades 10 and 11) from one urban Midwestern U.S. school district. Within that group, only chemistry teachers who were teaching stoichiometry at the time of the study were invited to participate.

Limitations

This study was limited to chemistry courses in which stoichiometry was being taught. The study was limited to an urban school district in the Midwestern United States. The findings might not be generalizable to high schools in suburban or rural school districts. This study focused on five high school teachers of chemistry. Teachers of other academic disciplines and teachers of chemistry at other academic levels (i.e., middle school or college) were not invited to participate.

Significance

I conducted this narrative study to explore the high school chemistry teachers' experiences teaching stoichiometry. It was my hope that by understanding how they explained stoichiometry to their students, the teachers would then analyze their own instructional styles or methods of delivering the concepts associated with stoichiometry. Analyzing the successful and unsuccessful teaching strategies used by the chemistry teachers in this study might help teachers in the school district to improve student achievement in stoichiometry in particular and chemistry in general. In addition, teachers might be more successful in getting their students to understand scientific concepts. Understanding the concept of stoichiometry can have a domino effect. As a result of more students understanding chemistry, more students might want to major in science and technology in postsecondary education. U.S. students are a minority in science- and technology-related fields (Mitchell, 1997; Stine & Matthews, 2009; Sturgis & Allum, 2004).

For the United States to stay competitive in a global economy, the country must increase the number of students choosing to major in science- or technology-related disciplines (Liu, 2009). Teachers, scientists, and political leaders must join forces to address the need of students to understand stoichiometry and chemistry and to improve the science literacy of the population in general. Students who can grasp such challenging concepts as stoichiometry have the opportunity to develop the skills necessary to consider the sciences as a possible career or field of study.

Summary

Teaching is a complex profession that involves continuous learning and self-reflection, both of which are necessary to improve student achievement. Science teachers are responsible for helping students to learn and think about science as a subject in which they can be successful (Huann-Shyang, Sung, & Treagust, 2005; Jarrett, 2009). Improving student achievement in stoichiometry can lead to deeper understanding of chemistry, one of the most challenging courses in science, and a potential increase in students majoring in science and technology-related fields of study at the postsecondary level.

All teachers should be aware of the ways in which students learn, and student achievement in stoichiometry can improve if science teachers consider students' MIs and learning styles. Not all students learn in the same manner or have the same types of MIs, so interviewing five high school teachers helped to identify instructional strategies and methods of delivery that were or were not working for them. By acknowledging the relationship between teaching styles and students' learning styles, student achievement in stoichiometry and chemistry in general could improve.

Transition Statement

This study has five separate but related sections. Section 1 introduced the problem and explained the purpose, conceptual framework, and significance of the study. Section 2, the literature review, presents the literature relevant to teaching and learning chemistry and the concept of stoichiometry. Section 3 explains the methodology. Section 4 reports the results, and Section 5 interprets the results and their significance to social change.

Section 2: Review of the Literature

Introduction

This section includes a comprehensive review of literature related to chemistry teachers teaching the concept of stoichiometry. The strategy used to complete the review of literature was to analyze books, dissertations, and peer-reviewed articles. Searches were performed through various library databases, including EBSCOhost, Education Complete, ERIC, ProQuest, and Thoreau Multiple. Key search terms were *science literacy, chemistry literacy, stoichiometry, science education, chemistry education*, *student achievement in science*, *student achievement in chemistry*, *multiple intelligence in science*, *multiple intelligence in chemistry*, *learning styles in chemistry*, *learning styles in science*, and *learning styles in stoichiometry*.

The review covers issues associated with teaching chemistry and stoichiometry; current discussions in the field of stoichiometry, chemistry, science literacy, teacher instruction of science, shortage of highly qualified science teachers, science teacher training programs, chemistry literacy, strategies in teaching stoichiometry, and learning styles; and the application of MIs to teaching science, chemistry, and stoichiometry.

Stoichiometry

In chemistry, the concept of stoichiometry is considered the most complicated concept to master (Hand, Yang, & Brusvoort, 2007). Stoichiometry is the study of quantitative aspects of the mass-mole number relationship, chemical formulas, and reactions (Brown, LeMay, & Bursten, 2013) and involves the mole concept and the balancing of chemical equations (Zumdahl, 2002). Stoichiometry is usually taught during the second semester of a high school basic chemistry class (Michigan Department of Education, n.d.). When the concept of stoichiometry is introduced, students' grades have a tendency to drop (E. Polk, personal communication, September 15, 2009), despite the teachers reinforcing the prerequisites of knowing how to write the symbol of a chemical formula and polyatomic or monatomic ion, writing a balanced chemical equation, and calculating molar mass. Teacher 1 stated that some students come to class not knowing or unable to remember the prerequisites.

The concept of stoichiometry is challenging to students but also is necessary for them to learn about other topics in chemistry, including gas laws, colligative properties, and chemical equilibrium (Evans & Leinhardt, 2008). Some students become frustrated when stoichiometry is introduced (M. Fidler, personal communication, January 17, 2010). Most of the frustration stems from not retaining previously learned material and not properly preparing or studying for the course (E. Polk, personal communication, September 15, 2009). However, stoichiometry is and remains important to understanding the part of chemistry that involves problem solving (Dahsah & Coll, 2007).

Students attempt to surface learn the concept by trying to memorize the steps necessary to solve various types of stoichiometric problems instead of trying to understand the overall concept (J. Ishakis, personal communication, September 15, 2009). For example, some students choose to memorize how to solve for the number of moles that are in 2.5 grams of calcium hydroxide specifically rather than try to understand the concept of how to convert grams of a substance to moles of a substance. Many students do not even try to grasp the concept of retaining the information needed to solve stoichiometric problems, such as knowing polyatomic ions, writing chemical formulas, and writing and balancing chemical equations (Croteau, Fox, & Varazo, 2007). Some students try many times to grasp the concept but fail (M. Fidler, personal communication, January 17, 2010).

Chemistry is a difficult branch of science to learn (Uce, 2009). Understanding stoichiometry is an important part of learning chemistry, but student understanding of this concept is low, with many students demonstrating surface learning only (Agung & Schwartz, 2007; Dahsah & Coll, 2007; Haidar & Al Naqabi, 2008). Some students lack the confidence and ability to master chemistry (Watanabe, Nunes, Mebane, Scalise, & Claesgens, 2007).

Teachers at one public magnet high school mentioned that students did well in chemistry until the concept of stoichiometry was introduced (J. Ishakis, personal communication, September 15, 2009; E. Polk, personal communication, September 15, 2009). Teacher 3 mentioned that over the past 10 years of teaching chemistry at a traditional high school, when the concept of stoichiometry was taught, students began to lose confidence in their ability to learn chemistry. In contrast, Teacher 1 argued that students have no more problems with stoichiometry than with any other concept in chemistry.

Suggestions for Teaching Stoichiometry

Stoichiometry is a concept that involves problem-solving skills and retention of prior knowledge (Okanlawon, 2010). Comprehensive and diverse instructional strategies are needed to improve student learning of stoichiometry (Arasasingham, Taagepera, Potter, Martorell, & Lonjers, 2005; Kazembe, 2010). Traditionally, in science (chemistry) education programs, teachers are taught the content area, but not how to teach the content. The concepts of learning and teaching should be symbiotic (Hoffman & McGuire, 2010).

The role of teachers is important to promoting student understanding of stoichiometry. Teachers must know how to present the material in creative and resourceful ways to ensure that their students are developing an understanding of the subject matter. “Subject matter knowledge alone, stoichiometry knowledge alone, or pedagogical knowledge alone are not sufficient for capturing the knowledge of good chemistry teachers” (Okanlawon, 2010, p. 111). In addition to being creative and resourceful, teachers also must be knowledgeable of their subject areas and connect theory to practical learning. For teachers to help students to learn about stoichiometry, they must pay attention to the development of traditional subject matter knowledge, stoichiometry knowledge, and pedagogy, as well as the interaction among these domains (Okanlawon, 2010). To teach stoichiometry in a meaningful manner, teachers must adapt their instructional strategies and modes of delivery so that they reflect students’ learning styles.

Chemistry

Chemistry is the foundation of many fields of science, including medicine, engineering, and technology (Evans & Leinhardt, 2008). Stoichiometry is one of the most difficult concepts in chemistry for students to grasp (Agung & Schwartz, 2007; Uce, 2009). It is reasonable to conclude that improving students’ learning of stoichiometry might open science-related careers to more students from different academic interests and backgrounds (Agung & Schwartz, 2007). Thus, this narrative study focused on obtaining stories of the experiences of high school chemistry teachers teaching stoichiometry.

Several studies have been conducted on ways to teach stoichiometry effectively. For example, Uce (2009) studied the impact of teaching stoichiometry through conceptual change strategies. Previous research has shown that conceptual change strategies, such as learning new concepts based upon previously learned concepts, are more effective than the traditional methods of lecturing and completing worksheets. Evans and Leinhardt (2008) compared a technology-rich stoichiometry review course with a text-based study guide using online technology. They found that the students had a significant advantage in learning when teachers used technology and multimedia to help them to understand stoichiometry. In addition, Arasasingham et al. (2005) used knowledge space theory (KST) to assess students' understanding of stoichiometry. They concluded that KST was useful in helping the students to understand stoichiometry.

Chemistry Literacy

One hurdle in the science curriculum is chemistry, a physical science that deals with the study of various types of matter and their changes (Chang, 2010). Chemistry is one of the most challenging science courses in high school and college (Gabel, 1999; Uce, 2009). In the state merit curriculum, chemistry is a requirement that typically is completed during students' high school sophomore or junior years (Ohio State Department of Education [OSDoE], 2012). Students should have completed a year of algebra before taking the chemistry course in high school (OSDoE, 2012). Along with math skills, students should come with a willingness to learn and the tenacity to work hard. Homework must be completed to facilitate learning (Bayram & Comek, 2009; Hwang, Chen, Shadiev, & Li, 2011). In contrast, because no set prerequisites are required for college chemistry, many college students who are taking the course are science majors or are enrolled in programs that require a science elective.

Chemistry is foundational to many other sciences. According to the Committee on Prospering in the Global Economy of the 21st Century (US), Committee on Science, & Public Policy (US; 2007), the global standing in chemistry of the United States is eroding, and fewer U.S. students are pursuing doctoral degrees in chemistry (American Chemical Society, 2010). More importantly, the United States also is having difficulty increasing the number of bachelor’s degrees being awarded in chemistry. The result has been a paucity of chemistry teachers for students in elementary school to Grade 12 (“Strengthening High School Chemistry Education Through Teacher Outreach Programs,” 2009).

The failure rate of high school students in chemistry courses remains high (Doughtery, Bowen, Berger, & Rees, 1995). Some high school students come into chemistry courses without the requisite math skills (Matthews, Adams, & Goos, 2009). Students might find it difficult to master the content because of their tendency to learn by rote or memory instead of connecting the concepts (BouJaoude & Attieh, 2008). For example, students might memorize the process to solve a particular problem, but when the teacher changes a variable, students become confused and cannot proceed to the next step. More importantly, chemistry is a demanding course that requires study time beyond in-class instruction, but students rarely are willing to put in the extra study time to be successful.

Chemistry is a core component of scientific literacy and remains a prerequisite science (Evans & Leinhardt, 2008). Many students are apprehensive about entering fields such as biology, medicine, nursing, and engineering because of the theoretical and practical knowledge of chemistry required (Lyons, 2006). Students at the college level are being denied entry to some programs if they do not pass the chemistry prerequisite required for enrollment in science-based programs (Dubetz et al., 2008). Improving student understanding of chemistry could increase the number of students entering fields of study that involve chemistry (Maltese & Tai, 2010).

Science Literacy

The shortage of science majors in the United States is contributing to a loss not only of economic competitiveness but also of standing in the science and technology fields (Maltese & Tai, 2011; Petrilli & Scull, 2011; Viadero, 2005). Technology is the driving force in the global economy; it needs scientists and experts in technology (Groff, Smoker, & Co-Directors, 2009; Holdren, 2008). To ensure a future workforce that is globally competitive, students need to be educated not only to use current technology but also to develop new technology for the future (President’s Council of Advisors on Science and Technology, 2010).

A concern exists in the United States regarding the loss of competitiveness in science growth development and job creation (National Science Teachers Association [NSTA], 2007). Because of this concern, President Obama made the commitment to increasing awareness of science and technology nationally to make the country more competitive (as cited in Prabhu, 2009). In addition to the shortage of scientists and engineers, the United States also is lagging in the development of strategies to deal with or solve the scientific crisis and technical problems that arise within the country (Cordero et al., 2010). Fewer U.S. college students are graduating with degrees in natural sciences and engineering; more importantly, the publication of scientific articles has been decreasing in the United States since the early 1990s (Froschauer, 2006; Maltese & Tai, 2011).

It is important to increase science literacy in the United States not only to ensure global competitiveness but also because science is present in the everyday lives of all citizens (Asunda, 2011; Doerfert, 2011; Eve, 2007; Guzzetti & Bang, 2011; Prabhu, 2009). These science-related issues include, but are not limited to, climate change, oil spills, flu epidemics, aids, cancer, and recall of foods and medicines. Teaching science literacy to students now will help them when they enter adulthood to become aware of scientific issues over which they have some control (Hodson, 2011). Increasing science literacy will give people the knowledge to make educated decisions regarding their lives and their children's lives (Hodson, 2011).

In 1995, the Third International Mathematics and Science Study (TIMSS, as cited in Ruthven, 2011) reported that Grade 12 students in the United States ranked 16th after being ranked second in Grade 4. These results place the United States ahead of Cyprus and South Africa. According to the NAEP (2000 as cited in Hechinger, 2011), American students in Grade 12 scored below proficient levels internationally on math and science.

More recently, according to the Program in International Student Assessment (PISA), the United States ranked 35th of 40 countries in math and science (as cited in Hammond & McCloskey, 2008), despite the exposure of all U.S. students to science throughout elementary, middle, and high school years.

Understanding why students are not performing or progressing in science is important (Fisher, Grant, & Frey, 2009). Many students fail to meet the state standards needed for science achievement established by the No Child Left Behind (NCLB). Students are graduating from high school without understanding core science concepts (Roseman & Koppal, 2008). However, a major goal of science education is to improve students' scientific thinking and understanding (Dori & Herscovitz, 1999) in an effort to increase their achievement and develop more positive attitudes toward science (Kanter & Konstantopoulos, 2010).

Science Achievement

Science achievement remains poor in many schools (Fisher et al., 2009). According to Britner and Pajares (2006), teachers need to consider the needs and abilities of their students if achievement in science is to improve. Traditionally, teachers have not accommodated students' learning needs and take a one-size-fits-all approach to education (Baker, 2004; Beck, 2007). Instruction should actively engage students (Hoffman & McGuire, 2010), but in many instances, students are not engaged in teaching strategies that support an interest in learning science (Annetta, Minogue, Holmes, & Cheng, 2009).

Many factors influence student achievement in science, including prior experiences in science as well as the qualifications and ability of the teachers. In addition, the science curriculum is weak in focus, depth, and rigor. Teachers' lack of content knowledge is another factor in poor student achievement. According to TIMSS, the USDoE is at fault for the decline of achievement in science because of its focus on systematic reforms (as cited in Ruthven, 2011). Teaching quality can influence achievement in science (Levesque, Wun, & Green, 2010).

Science teaching must be viewed not only as mathematical based but also language based if student achievement is to improve (Guzzetti & Bang, 2011). Scientists use words to explain, observe, name, and analyze. Teachers need to motivate students to view science as a language (Lan & Tan, 2008), but many students lack the ability to comprehend the language of chemistry. Science achievement can improve through hands-on activities to reinforce learning (Areepattamannil, Freeman, & Klinger, 2011). For example, by learning about the concept of conservation of mass through experimentation, students are able to draw the conclusion that mass does not change.

Teacher Instruction of Science

Vaino (2009) stated that instructional practices are influenced by what teachers believe about learning and instruction. Teachers' beliefs and expectations need to be considered if changes are made to their teaching practices (Buehl & Fives, 2009). For example, teachers believe that all students can learn, yet a gap exists between instructional practices and student learning (DeJesus, Almeida, Teixeira-Dia & Watts, 2007). To alleviate this disconnection, teachers must be cognizant of students' learning styles and modalities when planning lessons. Although lectures might be useful to introduce a concept, hands-on experiments or group activities better assess students' understanding of the concepts and transference of this knowledge into practice. The academic success and educational experiences of students also depend on teacher quality (Shore, 2009). In many cases, low-achieving students might be in classes led by low-achieving, unmotivated teachers (R. Johnson, personal communication, September 15, 2006). In addition, some teachers are not trained to teach students in the ways that they learn best (T. Cross, 2005).

Shortage of Highly Qualified Teachers

A major issue in the U.S. education system is the need to place qualified science and mathematics teachers in the classroom (Luft, Wong, & Semken, 2011). The supply of science and math teachers remains relatively small (Luft et al., 2011). According to Liu (2009), the quality of teachers is important to improving student achievement. The long-term shortage of science teachers is threatening the academic success of students (Hudson, 1996). Science teachers need a strong background in science and, more importantly, in their specific content areas to teach effectively (Harris & Farrell, 2007).

To their detriment, many school districts across the United States are starting the school year with a deficit of science teachers (NSTA, 2007). Some districts are even lowering their standards to fill open positions (Liu, 2009). In elementary and middle schools, many science classes are taught by teachers with little or no science experience or knowledge. As a result, these students are receiving poor science instruction (Harris & Farrell, 2007). More importantly, at the middle school level, the formative years for gaining an interest in science, many students are losing, not developing, their interest in science (E. Daniel-Jones, personal communication, January 17, 2007).

Teacher shortages in science and mathematics are the result of many factors. In the United States, teachers often are held responsible for low student achievement (American Federation of Teachers, 2011). Teachers are working harder but experiencing cuts in pay and benefits while dealing with increased class sizes. For example, the Midwestern urban school system that was the focus of this study is decreasing teacher services per pupil and increasing class sizes because of budgetary concerns. The contractual maximum class size of 35 for high schools had a projected increase to 48 students (R. Bobb, personal communication, April 25, 2011).

Many of the most talented science students are choosing careers in industry rather than the teaching profession. Dawson (2007) reported on the high teacher turnover rate and the exodus of many teachers within the first 5 years of entering the profession. Reasons cited by teachers for leaving the profession include long work hours; lack of support from administration, parents; and veteran teachers; poor student motivation; and large class sizes (Dawson, 2007). The shortage of highly qualified science teachers also is to the result of teachers retiring faster than new science teachers can be certified.

Teacher Training Programs

Individual universities determine the content and standards for teachers and influence career choices (Harris & Farrell, 2007). To become a high school chemistry teacher, the University of Wisconsin requires one semester of chemistry teaching, following a curriculum of chemistry as a major or a minor. At Ferris State University, located in Michigan, a student needs to complete a 4-year chemistry education curriculum, with teaching as a minor, and one semester of directed chemistry teaching at the secondary level. In Minnesota, a curriculum of chemistry as a major or a minor, followed by one semester of student teaching in chemistry, is required. In the teacher education college at Michigan State University, an additional 5th-year internship, in which students spend a year student teaching, is required to receive a chemistry teaching degree. Similarly, Northern Michigan University requires completion of chemistry courses, as well as a professional education sequence, to obtain certification as a high school chemistry teacher. Most colleges and universities require prospective chemistry teachers to have a major or a minor in the subject area.

According to the NCLB's Highly Qualified Teacher Plan (as cited in Harris & Farrell, 2007), teachers must hold elementary or secondary certification with a core content endorsement based upon a minor that has been completed successfully, and they must pass the Test for Teacher Certification. More importantly, highly qualified teachers know their subject areas and can deliver the material in ways that students can understand (Harris & Farrell, 2007).

To become chemistry teachers, college students need particular skills and must complete accredited student teaching programs, which are important in developing effective teachers (Taskin-Can, 2011). Effective chemistry teachers must have certain skills to be successful: They must be enthusiastic about science and be able to motivate and inspire students to learn the subject. They also must be problem solvers, creative thinkers, and time managers. Teacher training is important to help students to achieve, especially in science-related subjects (Skelton, Seevers, Dormody, & Hodnett, 2012). In many instances, teachers who are not qualified in particular subject areas can receive training through professional development workshops offered by school districts. Alternatively, teachers can be mentored by other teachers within their departments who can help with subject matter and provide suggestions for instructional delivery. Lastly, some teachers use self-study programs to improve their knowledge of their subject areas.

Technology

Using technology in chemistry has the potential to produce high-quality, inquiry-based education in the science classroom (Bayram & Comek, 2009). Teaching the concept of stoichiometry with technology harnesses students' interest, improves their understanding of the concept of stoichiometry, and enhances their overall understanding of chemistry (Sendlinger et al., 2008). Advancements in technology have changed the way teachers teach and students learn (Ertmer & Ottenbreit-Leftwich, 2010). Using teaching strategies that incorporate technology can enhance student performance. With the use of technology, teachers can structure learning activities to meet students' diverse learning needs (Guzey & Roehrig, 2009; Keengwe, OnChwari, & OnChwari, 2009).

Technology also can be used to facilitate the collection and analysis of experimental data. Using technology in the lab means the more efficient collection of data. The use of technology also provides students with opportunities to analyze experimental data quickly and efficiently. Examples of laboratory technology are digital pH meters, digital thermometers, electronic balances, and computer-based labs.

Another aspect of learning chemistry through the use technology includes online or distance learning. Online chemistry classes give students opportunities to revisit lessons at their own pace and time. In addition, the interactive ability of online courses facilitates the learning of stoichiometry (Evans & Leinhardt, 2008). With this facilitation, students' learning styles are being accommodated. Teachers should consider students' learning style when developing lesson plans and instructional strategies (Cutolo & Rochford, 2007).

Learning Styles

Students' problems learning stoichiometry might be related more to a disconnection between their learning styles and teachers' instructional strategies than to an understanding of the principles associated with stoichiometry (Haskell & Champion, 2008). Teachers must take students' learning styles into consideration when trying to determine why students are not achieving in chemistry (Boström, 2012). Learning styles are an important aspect of how and how well students learn (Holliday & Said, 2008). Because students have different learning style preferences, educators must provide them with instructional strategies that meet a variety of learning styles (Hoffman & McGuire, 2010). When students become aware of their own preferred learning styles, and when teachers accommodate those learning styles, students' frustration levels decrease (Alumran, 2008), and academic performance and attitudes improve (Wilson, 2012).

Learning styles include behaviors that provide clues regarding how people learn and adapt to their environment (Gregorc, 1979). The four major learning styles are visual, auditory, kinesthetic, and tactile (Sampson, Karagiannidis, & Kinshuk, 2010). Students with visual preferences learn best through visual information. Students with auditory learning styles favor acoustic stimuli, such as lectures or discussion. Students with tactile learning styles prefer to learn through interactions with textual materials, such as holding a pencil or touching a paper handout or example. Students with kinesthetic learning preferences learn by performing activities that promote physical involvement and the manipulation of objects (K. Dunn & Dunn, 1993; Sampson et al., 2010). Holliday and Said (2008) suggested that the most effective learning styles for chemistry students are tactile and auditory.

The most appropriate learning style methods for adolescents are Kolb and Kolb's (2012) experiential learning model (ELM); Gregorc's (1979) learning styles theory; K. Dunn and Dunn's (1993) learning style model; and Price's Learning Styles Inventory (as cited in Hawk & Shah, 2007; Peterson, Rayner, & Armstrong, 2009). Kolb and Kolb's ELM characterizes learning as a cycle that identifies the most effective type or mode of instruction or experience for a learner: thinking, feeling, doing, or watching (Chan, 2012). Kolb and Kolb's (2012) ELM is used to test a person's learning according to two polar dimensions: concrete experience versus abstract conceptualization and active experimentation versus reflective observation. Based upon these descriptions, learning styles can be categorized as one of four basic types: diverging, assimilating, converging, and accommodating (Chan, 2012). Closer inspection of the ELM suggested that learners tend not to stay equally in each step of the process but have a preference for certain parts of the cycle (De Jesus et al., 2007). Most chemistry teachers have converging and assimilating learning styles (Kamarulzaman, 2012).

Gregorc's (1979) learning styles theory specifies that all learners have two basic criteria from which to learn: their perceptions (abstract or concrete), and their preferred ordering preference (sequential or random; Reio, 2006). When these variables are combined, four types of learners are confirmed: concrete-sequential learners, concrete-random learners, abstract-sequential learners, and abstract-random learners. Concrete-sequential learners prefer organized hands-on activities, concrete-random learners perform best with the trial-and-error approach, abstract-sequential learners prefer organization and time to reflect to gain clarity, and abstract-random learners do well in an environment where connections are made with enough time to reflect and gain clarity (Gregorc, 1979).

The K. Dunn and Dunn (1993) model defines learning style as the way individuals begin to concentrate on, process, internalize, and retain new and difficult information. The model holds 21 elements that are divided into five stimuli and then further into subcategories. The five stimuli are environmental (sound, light, temperature and seating design); emotional (motivation, responsibility, task persistence, structure); sociological (learning alone, in pairs, with peers, as part of a team, with a teacher or authoritative figure, with a social variety); physiological (perceptual strengths such as auditory, verbal/kinesthetic, visual text or visual picture, tactile and/or kinesthetic intake, time of day, mobility); and psychological (analytic, global, reflective, impulsive; Boström, 2012). The model is most commonly used with adolescents.

According to R. S. Dunn and Dunn (1999), the most important stimulus of the model is the physiological, which comprises the subcategories of auditory, visual, tactile, and kinesthetic (movement). Learning the concepts of stoichiometry requires the ability to visualize, analyze, and solve problems (Arasasingham et al., 2005). Having difficulty visualizing can influence students' achievement in chemistry and attitudes toward science

(Arasasingham et al., 2005). The ability to understand the concept of stoichiometry also involves tactile and auditory learning styles (Jeon, Huffman, & Noh, 2005). Thinking aloud when solving problems helps students to understand their thought processes and those of other students (Jeon et al., 2005). Implementing diverse teaching strategies can support the different learning styles of students in a chemistry course and substantially improve student achievement (Dubetz et al., 2008).

Teachers should model science activities and accommodate students' learning needs and abilities to improve achievement in science (Britner & Pajares, 2006). One major difference between traditional and more contemporary methods of teaching is that modern teaching strives to accommodate individual differences among learners to improve achievement (Wu & Alrabah, 2009). Exploring learning styles and MIs continues to be relevant in K-12 education by helping teachers and learners become more aware of their own teaching and learning styles (Reio, 2006). Teachers' awareness of students' learning styles could improve student achievement in science (Britner & Pajares, 2006).

Teachers need to understand students' learning preferences because students come to class with different skills and learning styles. MIs refer to students' innate ability to learn (Lincoln & Rademacher, 2006). According to Kaya (2008) and Owens (2009), it is essential that teachers understand how students learn science so that they can more readily accommodate students' needs and abilities to improve their achievement in the subject. According to J. Cross (2007), in an optimal learning environment, teachers recognize and provide instructional strategies that address the strengths as well as the weaknesses in their students' learning styles and MIs.

Some controversy exists regarding the impact of matching students' learning styles to teaching styles and student achievement (Alumran, 2008). One argument is that when teaching strategies are geared toward students' learning styles, students can move to a higher level of learning (Wang, Wang, Wang, & Huang, 2006). Students benefit when teachers can identify the ways in which students give and receive information based upon their specific learning styles (Cutolo & Rochford, 2007). When students are taught in environments in which resources and teaching accommodate their learning styles, their achievement and attitudes improve substantially (Cutolo & Rochford, 2007). Not teaching to students' learning style can decrease their academic achievement (Cirkinoglu & Demirci, 2007).

Science teachers who are dedicated to improving student learning are always looking for ways to advance their own teaching and learning (Colannino, Hoyt, & Murray, 2004). Once teachers are aware of their students' MIs or learning styles, they are better able to help their students. Because mastering scientific concepts often is challenging for students, matching instructional strategies to students' learning styles might improve their academic achievement (Ucak, Bag, & Usak, 2006).

Students have preferences in how they learn new material (Wu & Alrabah, 2009). Learning styles refer to students' natural and preferred ways of learning new information and skills (Kolb & Kolb, 2012). Learning styles also include individual biological and psychological characteristics (Kazu, 2009). Students should be aware of the strengths and weaknesses of their learning styles and MIs (J. Cross, 2007; Gardner 2004).

Multiple Intelligences

Gardner's (1993) theory of MIs is useful in teaching stoichiometry with basic objects that allow students to focus on the concepts (Selman, Selman, Selman, & Selman, 2011). Using different teaching approaches can help students to master the concepts related to stoichiometry. Ozdener and Ozcoban (2004) implied that MIs can be used to improve student achievement in science.

Intelligence is an innate variable that influences learning (Prugsamatz, 2010). According to Gardner (1993), every child has the ability to develop one or more types of intelligence. Gardner's theory of MIs is based upon nine distinct intelligences that can function independently or interact to produce intelligent behavior (see Table 1).

Table 1

Gardner's Multiple Intelligences

Intelligence	Description
Linguistic	Reading, writing, understand spoken words
Logical mathematical	Solving math problems, balancing checkbook, doing a mathematical proof, logical reasoning
Musical	Singing, composing, playing a musical instrument, appreciating musical structure
Bodily kinesthetic	Dancing, athletics
Interpersonal	Understand another person's behavior, motives, or emotions
Intrapersonal	Understand who we are, what makes us behave as we do, and how we can change
Spatial	Getting from one place to another, reading a map packing suitcases in the trunk of a car
Naturalist	Understand patterns in the natural world
Existential	Understand religious and spiritual ideals

Note. "Successful Intelligence in the Classroom," by R. J. Sternberg & E. L. Grigorenko, 2004, *Theory Into Practice*, *43*(4), pp. 274-280.

According to Gardner (1993), each MI is a separate functioning system that can interact with the others to enhance performance. However, measuring intelligence separately might produce a profile of skills that is broader than would be obtained by measuring verbal and mathematical abilities alone. This profile could be used to facilitate educational and career choices (Sternberg & Grigorenko, 2004).

Gardner's (1993) theory of MIs categorizes individual learning styles and ways of processing information (Baker, 2004; Beam, 2000). Intelligence refers to the computational power of a mental system, and style refers to the customary way in which an individual approaches a range of materials (Gardner, 2004). Learning style is the preference by which people process, absorb, and retain information, whereas MI is the innate ability to learn (Lincoln & Rademacher, 2006). The heart of the theory is to respect people's differences, the multiple variations in the ways that they learn, the several modes by which they can be assessed, and the almost infinite number of ways in which they can leave a mark on the world (Armstrong, 1994). Matching teaching strategies to learning styles and/or MIs could create the ideal environment for teachers to teach and students to learn science (Wisniewski, 2010).

Cook (2007) suggested that instruction include activities that reflect MIs and real-world situations. MI instruction serves students by focusing on their strengths and showing them how to work around their weaknesses (Jackson, 2009). Douglass, Burton, and Reese-Durham (2008) noted that instruction rooted in the principles of MI can improve students' academic achievement. Teaching to students' MIs has a positive influence on learning (Ucak et al., 2006). When science activities include the principles of MI, students are stimulated to learn (Ozdemir et al., 2006).

The use of Gardner's theory of MIs can meet the needs of most students (as cited in Jackson, 2009). Students taught by traditional methods have a tendency to be passive and isolated thinkers (Hirsch, 2010). Students who are taught by teachers who use the principles of MIs often are more successful than those taught by traditional lecture (Gale, 2011). In addition, a curriculum that reflects MIs can enhance students' strengths and expand their learning possibilities (Gullatt, 2008). Lastly, chemistry teachers' use of MI strategies can help students to move beyond rote memorization and develop a true understanding of chemistry (Haskell & Champion, 2008).

Other Research

Okanlawon (2010) conducted a qualitative study with 14 chemistry teachers who had 5 to 20 years of teaching experience to determine pedagogical content knowledge. The study focused on how the teachers presented stoichiometry to students during the introductory phase of the lesson. The data were obtained from classroom observations and videotapes of the lessons. The purpose of the videotaping was to examine the activities used to teach the concepts associated with stoichiometry.

Results, which were based upon classroom observations of the teaching of stoichiometry, showed that the teachers had adequate knowledge of their content area, although improvement was needed in adjusting their instructional strategies to meet the needs of their students. One limitation of Okanlawon's (2010) study was the use of classroom observations and videotapes as the only data collection tools. Teachers and students often react differently when they know that they are being observed or videotaped, a situation that could have led to different results in the study. Further research is needed to discover how teachers present the concept of stoichiometry to their students and the strategies used to help the students to understand this concept.

Loxley (2009) conducted a case study to identify the practices that science teachers used in their classrooms to convince their students that science is relevant and useful in their lives. The three teachers who participated in the study developed lesson plans based upon a pedagogical model developed by Sutton (as cited in Loxley, 2009), who believed that instead of telling students about concepts in science, the students learn better if they can see the relevance of the concepts and apply them to real life. The teachers developed their lesson plans separately. In agreeing to participate in the study, the teachers continued with the school curriculum but changed their teaching methods to reflect the teaching model that had been discussed with Loxley. The teachers submitted their written lesson plans and then videotaped or audiotaped the classes. As an aside, Loxley indicated that the students had already been videotaped in several of their classes, so the videotaping was not obtrusive and did not result in differential behavior. Three case studies were conducted in which teachers were asked to find ways to persuade students about the importance of science concepts.

Results implied that the teachers did not take into account how scientific concepts would be presented and how the students would learn them. Science teachers are confronted with unique challenges (Loxley, 2009). They need to persuade students that science is relevant and valuable. They need to share their vision of the world with their students by developing theme-based lessons that are linked to real-world experiences. The limitation of this study was the use of three teachers' classroom lessons. Additional research is needed to support the use of Sutton's pedagogical model for teaching science and science-related concepts, such as stoichiometry.

Summary

The literature review showed that many students have difficulty learning chemistry because they lack the skills necessary to complete the course successfully. These skills include, but are not limited to, mathematical skills, critical- and analytical thinking skills, and study skills. Students who have the skills to be successful in chemistry do not take the time to learn the science properly. They do not study or take the time to learn the prerequisites of balancing chemical equations, naming and writing compounds, or understanding the mole concept.

In addition, the shortage of qualified science (i.e., chemistry) teachers has had a negative impact on students' decisions not to major in science-related fields (Aschbacher, Li, & Roth, 2010). The shortage of highly qualified chemistry teachers can result in students' receiving misinformation about the subject. Middle and high school are the formative years when students either embrace science and want to learn more about it or reject it in favor of easier courses (Harris & Farrell, 2007). Qualified science teachers are needed to increase students' exposure to science and science-related subjects. A shortage of highly qualified science teachers can limit students' choice of advanced course offerings (e.g., advanced placement [AP] chemistry, AP biology, AP physics, anatomy and physiology) in science at the secondary level (NSTA, 2007). Without additional exposure to science, students might decide not to further their education in science or choose science as a career. Teachers are the key to the success of U.S. students in the global market (American Education Research Association, 2010).

The number of science (i.e., chemistry) majors has decreased substantially (American Chemical Society, 2010). Many students often do not major in science because they are not prepared academically to pass college-level chemistry courses. As a result, the United States is continuously losing its global ranking in science in general and chemistry in particular.

Closing Statement

One of the more difficult concepts to learn in chemistry is stoichiometry. Evidence from the literature review showed that implementing technology, teaching to students' MIs, and changing teaching strategies to match students' learning styles can improve students' comprehension of the concept of stoichiometry and their overall understanding of chemistry. The purpose of this qualitative narrative study was to examine the experiences of chemistry teachers teaching stoichiometry. In Section 3, I provide a detailed explanation of the narrative research design and the qualitative methodology that I used to conduct the study.

Section 3: Methodology

Introduction

This section provides a description of the qualitative research design that I used. A qualitative narrative research design was appropriate to address the problem that in traditional science classes, chemistry teachers tend to ignore students' individual learning styles and do not consider using MIs as part of their instructional strategies, factors that can contribute to students' poor understanding of and underachievement in chemistry (J. Cross, 2007), particularly in regard to the concept of stoichiometry (Salamah & Schwartz, 2007). Not understanding important concepts in chemistry exacerbates students' frustration and contributes to their poor attitudes about the subject. I also explain my role as the researcher, the data collection procedures, selection of the participants, validity, and data analysis.

Research Design

I used a qualitative approach to gather the experiences of five high school chemistry teachers' teaching stoichiometry to students in Grades 10 and 11 in an urban Midwestern U.S. school district. Qualitative research requires the use of multiple methods that are interactive and humanistic (Creswell, 2003). The term *qualitative research* stimulates a narrative or analytical richness that presents details (Prakash & Kloltz, 2007). Qualitative research is the exploration of questions about the quality of relationships and processes rather than a list of specific techniques of analysis (Denzin & Lincoln, 2008).

Qualitative research starts with the assumption that social settings are unique and provide the way for researchers to examine social contexts as a whole rather than as disconnected variables (Hatch, 2002). These contexts cannot be investigated through quantitative research methods that use research questions and hypotheses to shape the purpose of a study. In contrast, qualitative research does not require the use of hypotheses (Creswell, 2009). In addition, most quantitative research begins with a theory, whereas in qualitative research, researchers make observations and formulate theories (Creswell, 2003).

Quantitative research involves numeric descriptions of opinions, attitudes, and trends, but qualitative research involves words (Creswell, 2003). Furthermore, in the quantitative method, data are collected through surveys, questionnaires, and record reviews. Conversely, the qualitative method collects data using semistructured interviews with open-ended questions, the collection of artifacts relevant to the study, and observations (Creswell, 2003). Qualitative research designs include phenomenology, ground theory, case study, ethnography, and narrative inquiry (Creswell, 2003; Merriam, 2002).

Justification of Type of Research

The qualitative research design that I used was narrative inquiry, which uses the participants' first-person accounts of experiences related to the phenomenon of interest told in story form (Merriam, 2002). A narrative research strategy was the most appropriate approach to address the problem in this study because the stories of these teachers had not been legitimated in previous research. Narrative research involves the study of individuals and their stories (Creswell, 2003). Narrative research is qualitative work that is "first-person accounts of experiences that are in story format having a beginning, middle and end" (Merriam, 2002, p. 286). The narrative studies can combine views from the participants' lives with those of the researcher in a collaborative effort (Clandinin & Connelly, 2005).

Phenomenological studies focus on the essence or structure of a phenomenon (Merriam, 2002). This research design involves looking at and developing patterns and relationships in the setting of the phenomenon over a long period (Creswell, 2003). In this kind of study, the researcher must not add a biased opinion of the phenomenon.

Grounded theory refers to deriving inductively from the data a theory that is grounded in the data based upon the participants' views of the topic being studied (Bloomberg & Volpe, 2008). Data are collected from a small number of participants over an extensive and prolonged period in order to develop meaning from their relationships with each other (Creswell, 2003; Merriam, 2002). Data analysis involves a constant comparative analysis technique that looks at similarities and differences between present and past data (Merriam, 2009).

Case study research refers to an intensive description and analysis of an issue that is important to an individual or a group (Merriam, 2002). This approach allows the participants to describe the issue in depth. During case studies, attention is focused on a particular location over a certain period of time (Merriam, 1988) and usually involves a single issue (Creswell, 2009; Merriam, 2002).

Ethnography refers to a cultural study of the beliefs, values, and attitudes that shape the behavior of a particular group of people (Merriam, 2002). In this design, researchers study the culture of a group using interviews and observational data collected over a long period (Creswell, 2009). This kind of study is associated primarily with anthropology (Merriam, 2002). The main sources of data for this strategy are observations (Creswell, 2003).

Research Question

In alignment with the research problem and purpose, the following research question was posed: What are the stories of chemistry teachers in an urban Midwestern U.S. school district about their experiences teaching the concept stoichiometry? One broad research question focused the study while remaining open to what could have emerged from the data (Bogdan & Biklen, 2007). As the data in any study are being collected and analyzed, the research question can be refined and modified, and additional questions posed, to fit better with how such studies are framed by the data (Stake, 1995).

Context of the Study

I conducted the study in an urban Midwestern U.S. school district that has seen a steady decline in student enrollment over the past 10 years resulting from parents losing jobs, families moving out of state, and students transferring to other school districts or to charter schools. Because of these factors, some schools in the district have closed or have been consolidated. In addition to population decreases, standardized student test scores also have declined in this school district. Because of this decline, some schools in the district have not met the criteria for adequate yearly progress (AYP). Presently, the district is going through a restructuring process.

At the time of the study, the student population in the school district was approximately 73,000 students in attendance at 100 schools. The school district has 10 high schools; chemistry teachers from five of these high schools participated in the study. The high schools were selected because their different characteristics reflected a broader representation of methods used by teachers to teach stoichiometry. Table 2 presents the demographics of each school.

Table 2

Demographics of the Five Schools in the Study

School/Teacher	Entrance requirement/school type	Student population	Graduation rate (%)	Attendance rate (%)
1	Exam/College prep	1,050	100.0	98.0
2	No requirements – All boys	230	70.9	85.0
3	Application	500	99.0	98.0
4	Alternative school	906	65.6	58.0
5	No requirements – All girls	618	65.8	86.0

Ethical Protection of Participants

In narrative studies, whom researchers are studying is just as important as the sample size (Case, Marshall, & Linder, 2010; Creswell, 2009). In addition, the, sample size depends on the depth of the narratives (Chase, 2005). The sample size is variable, with sampling continuing until data saturation occurs. Bogdan and Biklen (2007) defined data saturation as the “point of data collection where the information becomes redundant” (p. 68).

Once I received permission from Walden University's Institutional Review Board (IRB approval #03-03-14-0107085) to conduct the study, I informed the Midwestern U.S. school district of this approval. The district's office of research and assessment sent invitations to the principals of the participating schools to seek their approval for one chemistry teacher from each school to participate in the study. Once the principals gave their approval, I contacted one chemistry teacher from each school to solicit the individual's voluntary participation. All of the teachers accepted my invitation. Using the narrative method of inquiry, I collected the requisite data by conducting private face-to-face interviews with the teachers at the public library and at times convenient to them. The interviews ranged from 13 to 32 minutes. Prior to each interview, the participants signed the consent form.

Within 2 days of initial contact, each participant was given a consent form. I included a telephone number if the potential participant has any questions regarding participation in the study. I reminded the participants to retain a copy of the consent form for their records. Audiotapes of the interviews are stored in a locked cabinet in my home. The interview transcriptions are stored on my personal, password-protected computer. I will keep the interview data for 5 years, after which time they will either be securely erased or shredded.

Role of the Researcher

One characteristic of a qualitative study is that the researcher is the primary instrument for data collection and data analysis (Merriman, 2002). In a narrative study, the researcher's role is to move the relationship from interviewer-interviewee to narratorlistener (Chase, 2005). In this role, the quality of the data is dependent on the trust relationship that develops between the researcher and the participant (Josselson, 2007).

I have been a certified high school chemistry teacher for 26 years in the urban Midwestern U.S. school district that was the site of my research. I have taught in my present school, an examination high school, for the past 24 years. I am not in a supervisory position and have no authority over any teachers, either at my present school or at any other school in the district. My relationship with the participants did not affect data collection. During the interview process, the interviewer- interviewee relationship also was maintained.

As the principal investigator in this study as well as a chemistry teacher, I understand the difficulties that students have learning the concepts related to stoichiometry. As I conducted the semistructured, face-to-face interviews with the teachers selected for the study, I asked questions and probes without any prompts that could have reflected my own biases.

Participants

Qualitative research requires purposeful sampling (Bloomberg & Volpe, 2008). I chose purposeful sampling to select participants based upon their having specific characteristics needed to be included in the study (e.g., teaching high school chemistry in an urban school district; Bloomberg & Volpe, 2008). The five chemistry teachers represented the types of high schools in the school district (i.e., small examination, application, alternative, all boys, all girls). All of the participants taught stoichiometry. The sampling plan was to select one teacher from each type of school.

Teacher 1 taught at my school, which admits students through an examination process. This school is a citywide college preparatory school, and potential students must pass a placement test to be enrolled. For the most part, students at this school are motivated and intend to further their education at the postsecondary level. Many of them lean toward science as a major. Teacher 2 taught at an all-boys high school, a citywide comprehensive high school with male students admitted through an application process. Teacher 3 taught at a high school in which many students also are motivated and are planning to attend college. Though not tested, students are admitted through an application process. Parental involvement is evident. Teacher 4 taught at an alternative high school with students who are not as motivated and whose attendance is poor. This school is the last resort for many students before they are removed from the district. Teacher 5 taught at an all-girls high school, a city-wide comprehensive high school with female students admitted through an application process.

Data Collection

The interview questions focused on obtaining information to address the research question: What are the stories of chemistry teachers in an urban Midwestern U.S. school district about their experiences teaching the concept stoichiometry? Each interview was audiorecorded using a LG, G2 microrecorder: I also took field notes during the interviews, which were held at a private location in a suburban public library. Interviews were conducted from 4:00 p.m. to 6:00 p.m. Monday through Friday or on Saturday mornings from 10:00 a.m. to 12:00 p.m. in an effort not to conflict with instructional time and to accommodate the availability of the teachers.

Three separate interviews were conducted to create three data points that could be used in triangulation to improve the trustworthiness of the study. Following each interview, I transcribed the audiotaped responses. Then I met with the participant to review the transcribed story for verification in order to ensure completeness and accuracy. I made corrections to the story by incorporating any adjustments requested by the participant. If necessary, I met with each participant again to review the revisions and verify the accuracy and completeness of the story. To ensure the privacy of the interviewees, I identified the participants using numeric identifiers (Teacher 1, teacher 2, etc.). Only I knew the true identities of the interviewees.

The identities of all participants remained confidential; all information obtained during the interview process also was kept confidential. The participants were exposed to minimal risk as a result of joining the study. I will not include the names of any participants in any reports of the completed study.

Interviewing is a way to gather stories of the participants’ lived experiences regarding the phenomenon of interest (Siedman, 2006). Creswell (2009) defined the interview process as a way that participants and researchers communicate through dialogue in which open-ended questions are asked. Semistructured interviews are commonly used in education research (Coleman &Briggs, 2005). The goal of the interviewing is to have the participant recreate their experiences within the topic to be studied (Siedman, 2006). Face-to-face interviews are the most common form of data collection for qualitative research in the field of education (Coleman & Briggs, 2005).

Data Analysis

I used inductive analysis, a method of qualitative research data analysis that involves thinking from specific to general (Hatch, 2002). According to Hatch (2002), inductive analysis involves the following steps:

1. Place the data in categories based upon relationships using coding (Creswell, 2003). These categories or themes are organized according to similarities and differences in the interview responses of the participants. Coding should not begin until all interviews have been transcribed (Creswell, 2009). Using coding, researchers search for themes that emerge from the narratives by looking at patterns found in the data.
2. After categorizing the data, researchers identify the categories important to the study.
3. Researchers go back through the data to see whether the categories still stand and keep records of where the relationships are present in the data. This process facilitates a closer look at the data.
4. Researchers ensure that the categories are supported by the data.
5. Researchers complete the analysis within the categories to ensure depth.
6. Researchers search for themes and similarities within the categories.
7. Researchers construct master outlines of the categories and their relationships to their studies.

Once the codes are developed by inductive analysis, researchers analyze the themes for patterns. In my study, these patterns became the basis for the findings. I also reported discrepant data (Hatch, 2002).

After transcribing the interviews, I placed them in story form and sought approval of their accuracy from the participants. I read the interviews several times to find similarities and differences and then code and categorize the data. This process took several days of reading and then underlining, highlighting, and identifying key words. By looking at the key words and phrases, I began to see the emergence of the themes.

Methods to Address Trustworthiness

Trustworthiness is concerned with four dimensions: credibility, dependability, transferability, and confirmability (Sinkovics, Penz, & Ghauri, 2008). Credibility refers to having sufficient data to identify and verify reoccurring patterns in the data. Dependability refers to determining whether repeating the study with a different group would produce the same results. Transferability refers to the ability to apply the findings to other settings or situations. Confirmability refers to the need to ensure that the findings are as free of researcher bias as possible. The results should reflect what the interviewees offered in their stories rather than what the researcher expected them to provide.

After completing the final transcriptions of the interviews, I gave copies of the stories to the respective teachers for verification and asked them to make any additions, deletions, or changes to ensure the accuracy of the transcriptions. I asked the respective teachers to have the corrections back to me within 5 working days. If the transcription was not returned, I assumed that it was complete and accurate.

I used a peer debriefer to ensure that the data made sense. The debriefer had a master's degree in science education with an emphasis in chemistry. She also had 16 years of experience teaching chemistry at the high school level. Using a peer debriefer, member checking, and triangulation of the data added to the trustworthiness of the study. I present the results of the study in Section 4.

Section 4: Results

Introduction

I present the findings and themes, descriptions of the participants, and an explanation of the categorized data in Section 4. I explain how I collected the data, and I include excerpts from the transcribed responses to the interview questions. The purpose of the study was to obtain the experiences of high school chemistry teachers teaching stoichiometry.

Research Question

What are the stories of chemistry teachers in an urban Midwestern U.S. school district about their experiences teaching the concept stoichiometry?

Data Collection

Once I received IRB approval to conduct the study, I informed the Midwestern U.S. school district of this approval. The district's office of research and assessment sent invitations to the principals of the participating schools to seek their approval for one chemistry teacher from each school to participate in the study. Once the principals gave their approval, I contacted one chemistry teacher from each school to solicit their voluntary participation. They all accepted the invitation. Using the narrative method of inquiry, I collected the requisite data by conducting private face-to-face interviews with the teachers at the public library and at times convenient to them. The interviews ranged from 13 to 32 minutes. Prior to each interview, the participants signed the consent form.

The interview questions focused on obtaining information to address the research question: What are the stories of chemistry teachers in an urban Midwestern U.S. school district about their experiences teaching the concept stoichiometry? Each interview was audiorecorded using a LG, G2 microrecorder: I also took field notes during the interviews, which were held at a private location in a suburban public library. Interviews were conducted from 4:00 p.m. to 6:00 p.m. Monday through Friday or on Saturday mornings from 10:00 a.m. to 12:00 p.m. in an effort not to conflict with instructional time and to accommodate the availability of the teachers.

Three separate interviews were conducted to create three data points that could be used in triangulation to improve the trustworthiness of the study. Following each interview, I transcribed the audiotaped responses. Then I met with the participant to review the transcribed story for verification in order to ensure its completeness and accuracy. I made corrections to the story by incorporating any adjustments requested by the participant. If necessary, I met with each participant again to review the revisions and verify the accuracy and completeness of the story. To ensure the privacy of the interviewees, I identified the participants using numeric identifiers (Teacher 1, teacher 2, etc.). Only I knew the true identities of the interviewees.

Data Analysis

I used inductive analysis, a method of qualitative research data analysis that involves thinking from specific to general (Hatch, 2002). According to Hatch (2002), inductive analysis involves the following steps:

1. Place the data in categories based upon relationships using coding (Creswell, 2003). These categories or themes are organized according to similarities and differences in the interview responses of the participants. Coding should not begin until all interviews have been transcribed (Creswell, 2009). Using coding, researchers search for themes that emerge from the narratives by looking at patterns found in the data.
2. After categorizing the data, researchers identify the categories important to the study.
3. Researchers go back through the data to see whether the categories still stand and keep records of where the relationships are present in the data. This process facilitates a closer look at the data.
4. Researchers ensure that the categories are supported by the data.
5. Researchers complete the analysis within the categories to ensure depth.
6. Researchers search for themes and similarities within the categories.
7. Researchers construct master outlines of the categories and their relationships to their studies.

Once the codes are developed by inductive analysis, researchers analyze the themes for patterns. In my study, these patterns became the basis for the findings. I also reported discrepant data (Hatch, 2002).

After transcribing the interviews, I placed them in story form and sought approval of their accuracy from the participants. I read the interviews several times to find similarities and differences and then code and categorize the data. This process took several days of reading and then underlining, highlighting, and identifying key words. By looking at the key words and phrases, themes began to emerge (see Appendix B).

Findings

Based upon careful thorough analysis of the data, six themes emerged: difficult to teach, presentation of stoichiometry, relevancy, students' reactions, barriers, and gender differences. Each theme is discussed and supported with excerpts from the transcribed interview responses.

Theme 1: Difficult to Teach

This theme rose from the first interview question: Tell me about your experiences teaching stoichiometry. The teachers' responses were overwhelmingly similar in that they found it difficult to teach stoichiometry.

Teacher 1 responded, "In my experience teaching stoichiometry used to be very, very difficult task to teach. I call it an emotional loop. It has become easier over the years but never easy."

Teacher 2 commented, "My experiences teaching stoichiometry has been difficult. It is a concept that is a little farfetched for the student to achieve, and I usually have some difficulty with it unless he is an advanced chemistry student."

Teacher 3 stated, "Recently in my experience teaching stoichiometry, I find myself going back to the basics and giving them stepwise questions, and also stopping and saying,'Let's start over.' It's becoming remedial."

Teacher 4 responded:

> My experiences teaching stoichiometry has been challenging. It takes a lot of work. As a matter of fact this is perfect because I just taught it. I just finished the assessment yesterday. I gave them an assessment yesterday. It was a disaster.

Teacher 5 replied:

> My experiences teaching stoichiometry has been interesting. I get a lot of whining. Initially, when I explain what stoichiometry is the students are, “Well, we can do this.” They’re kind of confident, but once we get into stoichiometry, they think it’s a nightmare.

Theme 2: Presentation of Stoichiometry

When introducing the concept of stoichiometry, many of the teachers did so using activities to teach or help to teach the concept. This theme was developed from two interview questions: How do you present the concept of stoichiometry to your students? What methods do you use to introduce the concept of stoichiometry?

Teacher 1 said:

> In presenting the concept, generally we start our conversation about the mole. We start out with conversations about converting things that they're familiar with. For example, I have them dot a paper for a minute and we talk about the number of dots that they can make in a minute and I try to discourage them from listening to the person next to them on how they make your dots so that is not synchronized so they can see how quickly one minute or how much you can do in one minute and we go from there I had them to do conversions.

Teacher 4 responded:

Well when I first introduce the concept of stoichiometry, I start with recipes so I have the kids, you know if you have, I think I have like five to six different recipes and they chose a recipe and they worked in pairs, in groups of twos or threes, and then they have to decide if I had this recipe how can I make, let's say the recipe call for eight servings, what do I need to do to give 20 servings? So I started there, and they had a difficult time with that. They had a really hard time but after a while, they were like, "Oh, you don't know I get it." That was our first, that was our introduction. I did that and that was a segue into now you can apply them to chemistry if you try to make something you have to change the proportion, and how do you do that?

Teacher 5 stated:

One thing I have done in presenting stoichiometry is, I tell them to find a recipe to one of their favorite meals. What I need you to do is write down the recipe. Then I want you to write down everything you're going buy at the store to make that recipe. They're planning their little meal, and I explain it to them. Everybody figured out what they need to buy. I said, "Now, I want you to identify everything that you need to produce your lasagna." I have to kind of use other terms of the product reactants to begin with. Then I would say, "You want to make this one pan. How much does it require of this, this, and this to make it?" They're explaining their recipes, and I have them exchange their recipes between the two.

Theme 3: Relevancy

The theme of relevancy did not stem from one interview question. It was a common theme throughout all of the interviews. Some of the teachers used the concept of relevancy.

Teacher 1 stated:

> I try to make it plain. For example, taking a mole of pennies and calculating the number of dollars that, that is how hard it is. When you put dollar signs in front of it, then they really get it because we talk about what will happen if you won a big game. Where your place value would be with respect to winning the big game? And how much you will win if it were in pennies and you want a mole of pennies how many dollars that would be, how many place values so they could understand that you know it's really, really good news to win big game but if you want a mole of pennies that is we've taken a fortunes of some of the richest people in the world and try to convert those to how many moles they have and so once that decimal point starts getting way to the left of their value for people that we know are rich, then they can understand you know that concept a little more.

Teacher 5 remarked:

> First of all, I attack it with something they love, food. We all can relate to food. After that, everybody's made their pan of lasagna or their cake and everything. "So what do we got now? How much did it take for it?" I said, "How much you think you got left?" It may take a little time to do that. I try to make it a big thing, and then they can see it. Therefore, what if I say that those noodles are part of a

reactant. Then we identify it, and then use the term product and relate everything through, and they're like, "I like this. I get this." And even then, I say, "What's left? Well this is left." So I say, "So you can make another pan of lasagna," and they're, like, "Yeah." "So how many can you make?" So they try to make as many of their recipes with what they have.

I say, "When you've run out of [sauce 00:03:06], raise your hand." They were like, "Oh." I said, "What did you do?" "Well, I ran out of this." I said, "This is considered your limiting reagent. Good job! So you can't make any more. You're limited because of that one spaghetti sauce, which is one, really. You can't make any more product because of that. So that's extra, right? That's your excess." We kind of do that. I like to do the cookie recipe. I try to introduce that, and they kind of, "I like this, I like this." Well, let's relate it to it. That's how I hook them in, but once we get into the middle of it, it kind of changes. They say, "Let's go back to the recipes."

Theme 4: Students' Reactions

During the interviews, the teachers mentioned the students' responses of fear and apprehension toward learning about the concept. This theme came from the interview questions asking them to describe the students' reactions to this concept.

Teacher 1 stated, "The initial response of the students is stress. They are stressed out."

Teacher 2 commented:

When I first introduce the concept they are interested, but after few days of it, they lose interest because they just don't seem to grasp it right away. I tried different supplements. I asked them to look it up as much as they can using other ancillary materials and things. We come back to class, they still just don't have that interest level.

Teacher 4 stated:

Just like any other science concept, when I introduced the concept of stoichiometry , it was new, and so they were, like, "Oh, my God!" you know. They were "Ah, my God!" But I think they were sort of open to it, but it's like what do you call it, unfamiliar territory? So they didn't know what they were stepping into, so, you know.

Teacher 5 remarked:

Generally, some are scared when I introduce stoichiometry, but what is stoichiometry? We talk about what it is, and what's the concept, and everything referring to chemistry comes down to this. When we talk about this, I say, every product that you use comes from stoichiometry. Because it's how you put it together to make this. Some of their reactions are good. The ones who have been, that C or better students would be.

Now, my students who are not doing that well, at this point, they are ready to just shut down. I'm almost losing them, and I'm trying to find things to get them back up into the game. If you have students who are D/F students at this time, they're almost, they basically have given up at this point. When they see stoichiometry, they are so scared beyond the point, where they may even sit there, and pretend that they're taking notes, or listening to you, and they absolutely, you're gone, shut you down. You might pick them up at another chapter, but they completely tune you out.

In contrast, Teacher 3 experienced no fear or apprehension from her students:

The students are receptive after I introduced it. I have actually just taught the moles conversion in the beginning, but a lot of times since I've taught moles to grams and grams to moles, and then from moles to atoms, from atoms to moles, they continue to try to use the atoms, Avogadro's number because it's one of the simpler things where it's a cost, and it's always the same. I find that they're trying to slide that conversion factor up into our equation when it's not needed.

Theme 5: Barriers

A variety of barriers were mentioned in the interview responses. Three of them were math ability, gender, and basic preparation. This theme came from another interview question: What barriers do you feel are preventing the students from understanding and mastering the concept associated with stoichiometry?

Teacher 1 stated:

One of the barriers preventing the students from understanding, I think, is the fear factor. I think the word itself is a very intimidating word. It sounds hard. Because of that, it's very hard to demystify it, so we have to really be careful how we approach it.

Teacher 2 commented:

> The only barrier I think would be is the fact that they were not exposed to it in a previous science course. I think if all of them were introduced to it in a previous science course, may be even in 8^{th} grade, and then they would have some familiarity with it. It wouldn't be so foreign because for some students, it's just a foreign subject to them; and at that time of year, they are no longer interested in grasping something like that.
>
> I also think their mathematic ability is a barrier. They need to be very comfortable. Just like in any chemistry class, they need to be very comfortable in their mathematical ability. They need to be confident learners, and they have to be eager.

Teacher 3 stated, "Not being able to see it [stoichiometry] in action is a barrier I think. When it comes to the lab, it seems though you need to teach lab in for them to understand."

Teacher 4 remarked:

> I see many barriers that prevent the students understanding. Well first and foremost, math concepts. Then for the population that I teach, reading is also an issue for a lot of students. Vocabulary is a huge, huge issue, and I'm starting a, as a matter of fact when we were in the workshop, a quiz bee, a couple of weeks ago, the presenter gave us an idea that we try and we're doing it. We're working the vocabulary into word parts so that kids get the prefixes and the scientific prefixes and suffixes and try to decipher and decode those words. So that seems to be

working better than what we used to do because we used to the [inaudible 00:11:39] model and it wasn't working, the kids will just say, "Oh it's too much. I'm not going to do it." So math, reading and, like I said, the next big thing I think is the whole idea of this multistep process.

The critical thinking going from one step to the next, to the next, to the next, they get lost in that somewhere. But if I could only reinforce, and I do it every day, drilling them with metric units, following through with a unit and then, you know, like just a basic number sets, are you able to look at the number and tell that if I have a large number on top and a smaller number in the bottom, my number's going to be greater than 1 or vice versa, the number's going to be less than 1. Just those minimal things that they should have had way back in elementary and middle school, you know we spend so much time with that when this is the concept.

In contrast, Teacher 5 did not feel that mathematics was the problem:

I don't think math is a barrier, I think that they use it as an excuse, because when you look at ... to pass chemistry, the first semester, the first year of chemistry, is simple algebra. It's simple mathematics. You're not asking them to do cosine, tangent, or anything like that. Now when you give [inaudible 00:23:48] into something, it's a thinking process. I don't think the barrier is mathematics. I think the barrier is thinking. Chemistry asks you to think, not memorize. Chemistry is 98% application, and in order for you to apply something, you have to think. If

> you don't have the math skills behind it, it makes it worse, but I think that is used as an excuse to not accomplish stoichiometry.

Theme 6: Gender Differences

This theme did not emerge from a particular interview question. During some of the interviews, a few of the teachers discussed the differences between the boys and girls.

Teacher 1 stated, "The boys seem to learn stoichiometry faster because of the math. They don't learn their charges like the girls so the girls actually formula write faster."

Teacher 2 commented, "Boys have a little more patience working the problems than girls."

Teacher 3 asserted, "Boys tend to only want to use the numbers and won't write the units while girls are better at knowing the units."

Teacher 5 stated:

> In my years of teaching stoichiometry, I have noticed there is a difference between boys and girls. Years ago, I would have said there's no difference, but there is. Because when I taught at the other program, I could see my boys, they were more math people. We got to be honest; stoichiometry is math, math, math, math. Even though it's just algebra, it's simple math, to be honest. The boys were more willing to do it, whereas the girls were ... being in an all-girls school, I see with them with the boys not being present, the girls are there. They're there with me. They're there. They're answering questions. They're jumping on you. "Show me this. Let me see this."

> The girls, I would say, are stars, and we don't know it. I think the girls are stars, and we do not recognize it. We have a robotics team or engineering; you see it for the boys. Ooh, it's a male thing, but when the girls are like, oh let's try this. But they have the opportunity, especially from the middle school, up to the high school, they come into themselves, and they are star for them. And I can see the difference. Before, the girls in my class would have been as aggressive, as I see the ones now.

Discrepant Cases

According to Merriam (2002), discrepant data do not conform to the expected research outcomes. Only two pieces of discrepant data were evident. Teacher 3 experienced no fear or apprehension from her students. In relation to the interview question about the students' reactions to this concept, Teacher 3 stated, "The students were receptive after I introduced it [stoichiometry]." The additional piece of discrepant data was in relation to another interview question: What barriers do you feel are preventing the students from understanding and mastering the concept associated with stoichiometry?

Evidence of Quality

In Section 4, I discussed the evidence of quality and three methods to ensure the quality of the results: triangulation, member checking, and peer debriefing. I conducted three separate interviews to create three data points that could be used in triangulation to improve the trustworthiness of the study. If needed a total of three face-to-face interviews were required to review the stories to verify the accuracy and completeness was based upon the interviews to ensure that each participant had the opportunity to fully address topics that each teacher felt were significant. This process was member checking. I used a peer debriefer to ensure that the data made sense. The debriefer had a master's degree in science education with an emphasis in chemistry. She also had 16 years of experience teaching chemistry at the high school level. Using a peer debriefer, member checking, and triangulation of the data added to the trustworthiness of the study.

Summary

This section provided a narrative of the processes used in collecting and analyzing the data. The teachers were from five high schools with various demographics. The transcribed interview responses and development of themes showed the different experiences, successful and unsuccessful, that these chemistry teachers faced when introducing the concept of stoichiometry to their students. In Section 5, findings, implications for social change, and recommendations for further study are discussed.

Section 5: Findings and Social Change

Introduction

After careful investigation, I found that student performance on assignments and assessments indicated that they had mastered the three individual basic stoichiometric concepts of writing a compound; writing a balanced equation; and comprehending the concept of a mole, a unit of measurement used in chemistry to express amounts of a chemical substance (Bureau international des poids et mésures, n.d.). However, when they had to put these concepts together, students could not grasp the concept of stoichiometry, which is the integration of the three concepts. Students were not applying the concepts, synthesizing the information, and problem solving in ways that could help them gain an understanding of stoichiometry.

Chemistry is one of the most challenging courses in the high school science sequence (Uce, 2009). Many students often do well in chemistry until the teacher introduces the concept of stoichiometry. Once that happens, their attitudes toward chemistry turn negative, and their understanding and achievement in chemistry begin to decline (Salamah & Schwartz, 2007). In my experience, students demonstrate poor achievement and understanding in stoichiometry in several ways: poor grades on tests and quizzes, missing or incomplete assignments, lack of class participation, poor class attendance, and reduced time on task.

Upon further investigation, I found that other chemistry teachers in my department were having the same problem, so I began to wonder whether teachers in other schools in the district were having similar problems. They were. This revelation was the impetus for this study. This qualitative study used a narrative inquiry design to study chemistry teachers' experiences teaching the concept stoichiometry. I conducted private, face-to-face interviews with five chemistry teachers from high schools throughout the district. Analysis of the data led to the emergence of several themes: difficult to teach, presentation of stoichiometry, relevancy, students' reactions, barriers, and gender differences.

Interpretation of the Findings

This interpretation of the findings starts with the conclusions based upon the results discussed in Section 4. I explained how the findings speak to the research question and then discuss the practical application of the findings. The findings are in direct correlation to the review of the literature. Teachers must be knowledgeable, creative, and resourceful in their subject areas to help students to learn stoichiometry (Okanlawon, 2010). To teach stoichiometry in meaningful ways, the teachers adapted their instructional strategies and modes of delivery to reflect their students' learning styles.

Summary of Interview Data

Research Question

This study was guided by one broad research question: What are the stories of chemistry teachers in an urban Midwestern U.S. school district about their experiences teaching the concept stoichiometry? The question brought forth detailed responses to the interview items. Summaries of the responses follow.

Interview Questions

Question 1: Tell about your experiences teaching stoichiometry. The teachers' reactions were similar: "It was a disaster," "it was difficult," "apprehension," "it's a nightmare," "it's an emotional loop," and "it's confusing to the students."

Question 2: How do you present the concept of stoichiometry? Thus question produced a variety of answers: Two teachers presented the concept by comparing stoichiometry with cooking recipes. Others started by having conversations about the mole and how to solve the concept in steps.

Question 3: Describe the students' reactions to this concept. One teacher remarked that she got blank stares, another stated that the students were excited at first and then lost interest and want to know what the point was, and one other teacher remarked that the students were stressed out.

Question 4: What methods do you use to introduce stoichiometry? One teacher reworked the practice problems, another used the textbook and any online chemistry, another introduced the concept using demonstrations and activities, another used lecture and problem-solving techniques, and yet another used recipes and reviews.

Question 5: When do you present the concept of stoichiometry during the chemistry course? Many of the teachers responded that they taught it after teaching the concept of balancing equations; others stated that they followed the pacing chart.

Question 6: How do you ensure that the objectives are being met? One teacher gave the objectives at the beginning of the lesson. Two teachers used testing and gave a lot of quizzes, another gave multiple problems, and another had the students write a flow chart.

Question 7: What barriers do you feel are preventing the students from understanding and mastering concepts associated with stoichiometry? A variety of answers were given. One teacher stated not being introduced to the concept in previous science courses, another remarked on the students' lack of math skills, another commented on the students' ability to think, another remarked that the students were intimidated, and yet another stated that the students could not see it (stoichiometry) in action.

Question 8: What are the strategies you use to help students understand and master concept associated with stoichiometry? Many of the teachers used a combination of handouts, labs, technology, tutoring, and discussion; one teacher stated that tutoring helped the most.

Question 9: What instructional methods are not useful in teaching the concepts associated with stoichiometry? Two teachers remarked that using the book alone did not work, another stated that using the Internet did not help, and others remarked that jumping into the problem and going for it did not work.

Question 10. What types of technology are used when teaching stoichiometry? One teacher did not believe in technology, but the other teachers used a variety of technology that included smart boards, virtual labs, PowerPoints, YouTube, and clickers.

Question 11: What methods do you use to assess students' understanding and mastery of concepts associated with stoichiometry? One teacher used the school district test, three used traditional testing and 5-minute quick quizzes, and another assigned a problem to a table so that the students could work on the problem as a way to assess their learning.

Discussion

After I developed the themes, I analyzed them to determine how well they reflected the research question: What are the stories of chemistry teachers in an urban Midwestern U.S. school district about their experiences teaching the concept stoichiometry? Analysis of the data identified many emerging themes: difficult to teach, presentation of stoichiometry, relevancy, students' reactions, barriers, and gender differences.

Difficult to Teach

Finding it difficult to present the concept of stoichiometry to students reflected previous results mentioned in the literature. In chemistry, stoichiometry is the most complicated concept to master (Hand et al., 2007). Chemistry is a science that many students find difficult to understand (Uce, 2009). Although stoichiometry is a challenging concept to learn, it is foundational to learning other concepts in chemistry (i.e., concentration and gas laws; Evans & Leinhardt, 2008).

The teachers found themselves going back to the basics of reviewing compound writing, balancing equations, and calculating molar mass. Teacher 1 described teaching stoichiometry as an emotional loop, with some students coming to class not knowing or unable to remember the prerequisites or basics. Teacher 3 commented, "I find myself going back to the basics and teaching it stepwise, but even taking it stepwise, the students are still unable to put all the pieces together." Teacher 4 stated that teaching stoichiometry was difficult because the students had no motivation to learn.

Many students do not try to take hold of the concept of retaining the information needed to solve stoichiometric problems, such as knowing polyatomic ions, writing chemical formulae, and writing and balancing chemical equations (Croteau et al., 2007). Some students try numerous times to take hold of the concept but fail (K. Jenks, personal communication, February, 12, 2012). They attempt to surface learn the concept by memorizing the steps needed to solve the problem instead of trying to understand the concept (J. Ishakis, personal communication, September 15, 2009).

Teachers realize that most of the frustration comes from students not retaining previously learned material and not studying for the class (E. Polk, personal communication, September 15, 2009). In addition, some students do not have the confidence and ability to master chemistry (Watanabe et al., 2007). Because of the complexity of the material and the lack of understanding by students resulting from not studying and retaining the information necessary to learn the content successfully, stoichiometry remains a challenging topic to learn (Okanlawon, 2010).

Relevancy and Presentation of the Concept of Stoichiometry

The way in which stoichiometry is presented is important to understanding chemistry. Teaching stoichiometry by comparing it to recipes helped some students to understand the concept. Teacher 5 noted that relating the concept to the students' lives gave them a sense of relevance in that they wanted to know why and how it related to them. Teacher 1 started the class by having conversations about things that the students were familiar with, such as simple conversions to help them to develop an initial understanding of the concept. Teacher 2 felt that the manner in which stoichiometry was presented in the textbook was adequate for students to understand.

Barriers and Gender Differences

Students face many barriers when they are introduced to stoichiometry: lack of ability in mathematics, lack of knowledge of prerequisites, and fear. Teacher 4 said, “But the basic problem is the kids’ math skill.” Teacher 1 noted, “One of the barriers preventing the students from understanding, I think, is the fear factor. The initial response to the introduction of stoichiometry is stress and intimidation. Then students are stressed out.”

Many students do not have the mathematical ability to do stoichiometry, with the result that they feel intimidated by the concept. To complete calculations in stoichiometry, Teacher 1 stated that “part of the reason they are afraid is it goes back to dimensional analysis [a systematic mathematical way of solving problems].” Teacher 2 felt that “students must be comfortable with their mathematical ability.”

The fear of mathematics also translates into chemistry, which deals with calculations (Obande, 2003). The literature has shown that boys have a tendency to perform better than girls in problem solving in chemistry (Evans, Yaron, & Leinhardt, 2008). Eriba and Sesugh (2006) conducted a study showing that boys outperformed girls in learning the concept of stoichiometry because of the calculations involved in the concept. Based upon a comment from one of the participating teachers, boys had a tendency to do better in stoichiometry than girls because boys were better with numbers;

however, girls had a propensity for learning the prerequisites to do stoichiometry (i.e., writing chemical compounds and writing balanced equations). Teacher 5 commented on a difference in boys and girls in learning the concept of stoichiometry, noting that "years ago, I would have said there is no difference, but there is. Because I taught at another program, I could see my boys, they were more math people."

Conceptual Framework

The conceptual framework of the study was based upon constructivist theory, which helped me to analyze the qualitative interview data. Constructivism is a view of how we come to know or understand (Taskin-Can, 2011). Analyzing the transcriptions helped me to understand and construct the best methods to teach and deliver the concept of stoichiometry. Using a constructivist approach allowed me to analyze the stories about their experiences teaching stoichiometry, initially by individual interview and then across interviews to develop themes and identify patterns in the data.

Even though the teachers found stoichiometry difficult to teach, the reactions of the students when the concept was introduced discouraging, and their students' lack of mathematical ability, they still remained hopeful. One commonality evident in the study was that the teachers wanted to help their students by using a multitude of strategies, such as by performing labs and teaching through differentiated instruction (DI). Each teacher infused laboratory experiences while teaching the concept of stoichiometry. Students learn by doing (Smart & Csapo, 2007), so the teachers felt that activities were important to the students in getting them to become even remotely interested in to trying to learn the concept of stoichiometry.

DI is a way of teaching that involves modifying instruction to fit the needs of the students (Tomlinson, 2005).Teacher 1 stated, “I use a variety of strategies to help the student understand.” One strategy was to use comparisons to real-life applications, and have student do presentations to increase their understanding. Teacher 2 used the text and computers to aid in improving students’ understanding of stoichiometry, noting that “I use technology in my classroom frequently. I try to incorporate many strategies to help students understand stoichiometry, and then I ask them to resort to technology, also.”

Teacher 3 commented:

> I typically do lecture and problem solving, and then move into actual activities where I’m actually going to have them calculate how many grams of a substance they make. The strategy I use most to help understanding is tutoring goal focus, communication adequacy, optimal power equalization, resource utilization, cohesiveness, morale, innovativeness, autonomy, adaptation, and problem-solving adequacy.

Teacher 4 indicated:

> I start with recipes, I have five to six different recipes and they chose a recipe and they worked in pair in groups of twos or threes and then they decide if I had this recipe, how can I make it? To aid in their understanding, I also work with them in small groups.

Teacher 5 stated:

> We start by having a classroom discussion about stoichiometry and then I attack it with something they love, food. We all can relate to food. After that everybody’s

made their pan of lasagna or their cake and everything. How much did it take for it? How much you think you got left?

Student learning in chemistry can be enhanced through laboratory activities (Cacciatore & Sevian, 2009). The teachers stated that the labs were a key factor in helping students to learn and understand the concepts. Teacher 1 commented, "I think that but the one thing that I really above everything else, I try to do a lab as it relates to that skill." Teacher 3 used labs as a way of reinforcing the concept. Teacher 5 said, "I have the students conduct the simplest lab to aid in understanding."

Strategies That Did Not Work

Teacher 2 commented that using the textbook alone was not a good instructional strategy. Teacher 3 also found that using the textbook was not helpful. Teacher 4 stated, "Depending on the book does not work for me, [and] worksheets are not really helpful because you still have to instruct, so giving a lot of independent work does not help." Teacher 5 said, "One of the instructional methods I did not find useful was the Internet. I told them over the years, the Internet, everything on the Internet is not correct."

Implications for Social Change

The United States is facing a shortage of students majoring in science-related fields and is experiencing a deficit of students who are actually achieving in science (Maltese & Tai, 2011). U.S. students have been regarded as minority participants in science-related fields (Bybee & Kennedy, 2005). Various sources have cited a report from the NAS that any leadership advantages that the United States had in the fields of math and science are declining (Loucks-Horsley & Matsumoto, 1999; President's

Council of Advising on Science and Technology, 2010; Stiles et al., 2009). Educators in the United States need to encourage more students to major in math and science (Cordero et al., 2010). A shortage of 70,000 engineers had been predicted to happen by 2010 (Kekelis & Gomes, 2009). The shortage of scientists and engineers has contributed to the shortfall in scientific inquiry and discovery (Cordero et al., 2010; Kekelis & Gomes, 2009). Because of the shortage of U.S. students majoring in science and technology, the country faces losing its economic status in the 21st century (Guiso et al., 2011).

Educators are just beginning to recognize and understand the role of science teachers in determining the way in which science is taught and learned (Okanlawon, 2010). By increasing the number of students learning stoichiometry, more students will become more successful in passing chemistry courses and meeting the requirements to enroll in many science-related fields of study at the postsecondary level. If more students are successful in chemistry, then more students will earn degrees in the science, technology, engineering, and mathematics (STEM) fields. The impetus for this study was the desire to help chemistry teachers to open up careers in science and engineering to more U.S. students from various backgrounds.

Understanding how teachers explain stoichiometry to their students can help other chemistry teachers to analyze their own instructional styles and delivery methods of the concept. Analyzing the success or failure of specific instructional strategies used by the chemistry teachers in this study can help other chemistry teachers in the school district to improve student achievement in stoichiometry in particular and chemistry in general. In addition, teachers' efforts to help their students to understand scientific concepts will become more successful. For the United States to be more competitive in a global economy, it must increase the number of high school students choosing majors in science- or technology-related disciplines as they enter postsecondary education (Liu, 2009).

Recommendations for Action

Chemistry is one of the most challenging courses in the high school science curriculum (Uce, 2009). Teachers need to be aware of the learning styles of all their students (Entwistle & Newble, 1986; Wehrwein et al., 2007). Specific to this study, chemistry teachers must attempt to match their instructional styles to the learning styles of their students (Watters & Watters, 2007). The results of this study showed that the teachers were successful when they tailored their instructional styles the learning styles of the students. The teachers used a variety of instructional methods (e.g., recipes, labs, real-life examples, and technology) to help their students to master stoichiometry.

Results of the study will be shared with the participating teachers as well as with other chemistry teachers in the school district. Through professional development at the state level, the results will be shared with chemistry teachers across the state. Another way to share the results of the study could be by presenting the findings at the National NSTA’s national conference or publication in a science.

Recommendations for Further Study

The results identified a variety of strategies to teach stoichiometry, a saturated mathematical concept, to students. The results indicated that of the teachers believed that students were not ready mathematically to be successful in the course. Future researchers could explore ways to prepare students to be mathematically ready for chemistry. The results also showed that when the teachers introduced stoichiometry, the students became apprehensive and fearful. Future researchers could explore ways to present the concept to students in more receptive ways, such as introducing an integrated science course prior to chemistry. The results also showed that according to the teachers' comments, boys had a tendency to learn stoichiometry more easily that the girls did. Future researchers could investigate ways to help girls in an effort to decrease the achievement gap in chemistry.

The teachers had difficulty presenting the concept of stoichiometry to students, so I recommend that teachers participate in professional development activities specific to teaching stoichiometry and other mathematically involved concepts in chemistry. Future researchers also could explore ways to improve the achievement of students in other areas of chemistry that are heavily immersed in mathematics and problem solving, such as equilibrium, chemical kinetics, thermodynamics and electrochemistry.

Reflections on My Experience

This study was special to me because I am an AP chemistry teacher. I have been teaching chemistry for more than 25 years. I fail to understand why it is that when students have to study stoichiometry, it seemed as though they have forgotten how to think and cannot remember what they had been taught previously. Conducting this study allowed me to see the different ways that I can teach this concept.

Conducting the interviews and analyzing the data gave me insight into some of the changes that I need to make in my own instructional strategies and planning. Until I conducted this study, I had not noticed the difference between girls and boys in learning the concept of stoichiometry. I started paying closer attention and discovered that the boys in my chemistry class generally were doing better mathematically. When problem solving was involved, the boys excelled, but the girls did better memorizing their polyatomic ions and writing and balancing equations. I have to pay more attention to whether or not the girls in my classes are comprehending the material.

Looking at the subject matter through the experiences of other teachers enabled me to recognize my own effectiveness and ineffectiveness as a teacher. I realize now that knowing the material is not enough to communicate the information to the students.
I saw how DI can be used to help students to understand the concept of stoichiometry. The teachers in this study used a variety of strategies to help their students to understand the concept. I learned that teachers can use something as simple as cold water or food to teach the students about limiting reactants, a stoichiometric concept.

Meeting and interviewing each teacher was refreshing because although each teacher had a different teaching background, shared the common element of wanting to help their students to understand the concept of stoichiometry and were willing to work hard at achieving that goal. I was able to see the differences in how students from different classrooms handled learning the concept of stoichiometry. I came to realize that the teachers were going through challenges similar to mine when teaching this concept.

Conclusions

Hearing the stories of other chemistry teachers allowed me to see how they were teaching stoichiometry. The five teachers willingly shared their experiences, something that might help other teachers to teach the concept of stoichiometry. This study might help other teachers to help their students to overcome the barriers to understanding stoichiometry. If conquering this concept means that more U.S. students will enter STEM-related fields, then the country might be able to once again compete on a more equal footing in the global arena. Efforts must be made to stop the exodus of students from STEM-related fields.

References

Agung, S., & Schwartz, M. (2007). Students' understanding of conservation of matter, stoichiometry and balancing equations in Indonesia. *International Journal of Science Education*, *29*(13), 1679-1702. doi:10.1080/09500690601089927

Alumran, J. A. (2008). Learning styles in relation to gender. Field of study and academic achievement for Bahraini University students. *Individual Differences Research*, *6*(4), 303-316.

American Chemical Society. (2010). *U.S. chemistry employment and unemployment: Data, implications & trends* [Research brief]. Retrieved from http://portal.acs.org/preview/fileFetch/C/CNBP_024760/pdf/CNBP_024760.pdf

American Education Research Association. (2010). AERA presents Richard Ingersoll's research on math and science teacher shortage at CNSF exhibit on Capitol. *Educational Researcher, 39*(5), 429-430. doi:10.3102/0013189X10375074

American Federation of Teachers. (2011). Math and science teacher shortage continues. *AFT newsletter*, *2*(1), 4-5.

Annetta, L. A., Minogue, J., Holmes, S. Y., & Cheng, M.-T. (2009). Investigating the impact of video games on high school students' engagement and learning about genetics. *Computers & Education, 53*(1), 74-85. Retrieved from www.sciencedirect.com

Arasasingham, R., Taagepera, M., Potter, F., Martorell, I., & Lonjers, S. (2005). Assessing the effect of web-based learning tools on student understanding of stoichiometry using knowledge space theory. *Journal of Chemical Education, 82*(8), 1251-1262. doi:10.1021/ed082p1251

Areepattamannil, S., Freeman, J., & Klinger, D. (2011). Influence of motivation, self-beliefs, and instructional practices on science achievement of adolescents in Canada. *Social Psychology of Education: An International Journal, 14*(2), 233-259. doi:10.1007/s11218-010-9144-9

Armario, C. (2011). Less than half of students proficient in science. *The Associated Press.* Retrieved from http://www.dailynews.com/

Armstrong, T. (1994). *Multiple intelligences in the classroom.* Alexandria, VA: ASCD.

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspirations in science, engineering, and medicine. *Journal of Research in Science Teaching, 47*(5), 564-582.

Asunda, P. (2011). Open courseware and STEM initiatives in career and technical education. *Journal of STEM Teacher Education, 48*(2), 6-37. Retrieved from scholar.lib.vt.edu

Baker, R. J. (2004). *Where does your burger come from? Best teaching practices for reaching all learners: What award-winning classroom teachers do.* Retrieved from books.google.com

Bayram, H., & Comek, A. (2009). Examining the relations between science attitudes, logical thinking ability, information literacy and academic achievement through Internet assisted chemistry education. *Procedia-Social and Behavioral Sciences, 1*(1), 1526-1532. doi:org/10.1016/j.sbspro.2009.01.269

Beam, K. (2000). *A comparison of the theory of multiple intelligences instruction to traditional textbook instruction in social studies of selected fifth-grade students* (Doctoral dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. 9957910)

Beck, J. (2007). An exploration of the relationship between case study methodology and learning style preference. *Journal of Science Teacher Education, 18*(3), 423-430. doi:10.1007/s10972-9056-5

Bloomberg, L. D., & Volpe, M. (2008). *Completing your qualitative dissertation: A roadmap from beginning to end.* Thousand Oaks, CA: Sage.

Bogdan, R. C., & Biklen, S. K. (2007). *Qualitative research for education: An introduction to theory and methods* (2nd ed.). Boston, MA: Allyn & Bacon.

Boström, L. (2012). Do ten-year-old children in Sweden know how they learn? A study of how young students believe they learn compared to their learning styles preferences. *International Education Studies, 5*(6), 11-23. doi:10.5539/ies.v5n6 p11

BouJaoude, S., & Attieh, M. (2008). The effect of using concept maps as study tools on achievement in chemistry. *Eurasia Journal of Mathematics, Science & Technology Education, 4*(3), 233-246. Retrieved from http:/www.ejmste.com

Britner, S., & Pajares, F. (2006). Sources of science self-efficacy beliefs of middle school students. *Journal of Research in Science Teaching, 43*(5), 485-499. doi:10.1002/tea.20131

Brown, T., LeMay, H., & Bursten, B. (2013). *Chemistry: The central science* (12th ed.). Upper Saddle River, NJ: Prentice Hall.

Buehl, M. M., & Fives, H. (2009). Exploring teachers' beliefs about teaching knowledge: Where does it come from? Does it change? *Journal of Experimental Education, 77*(4), 367-408. doi:10.3200/JEXE.77.4.367-408

Bureau international des poids et mésures. (n.d.). Unit of amount of substance (mole). [International System of Units (SI) brochure, Section 2.1.1.6]. Retrieved from http://www.bipm.org/

Bybee, R., & Kennedy, D. (2005). Math and science achievement. *Science, 307*(28), 481. Available from http:/www.proquest.com

Bybee, R., & Stage, E. (2005). No country left behind: International comparisons of student achievement tell U.S. educators where they must focus their efforts to create the country needs. *Issues in Science and Technology, 21*(2), 69-75. Retrieved from http://www.issues.org

Cacciatore, K., & Sevian, H. (2009). Incrementally approaching an inquiry lab curriculum: Can changing a single laboratory experiment improve student performance in general chemistry. *Journal of Chemical Education, 86*(4), 498. doi:10.1021/ed086p498

Case, J. M., Marshall, D., & Linder, C. J. (2010). Being a student again: A narrative study of a teacher's experience. *Teaching in Higher Education, 15*(4), 423-433.

Center for Teaching Quality. (2006). *Spotlight: Teacher working conditions*. Retrieved from http:/www.teachingquality.org

Chan, C. (2012). Exploring an experiential learning project through Kolb's Learning theory using a qualitative research method. *European Journal of Engineering Education, 37*(4), 405-414. doi:10.1080/03043797.2012.706596

Chang, R. (2010). *Chemistry* (10th ed.). New York, NY: McGraw Hill.

Chase, S. E. (2005). Narrative inquiry: Multiple lenses, approaches, voices. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (3rd ed., pp. 651-679). Thousand Oaks, CA: Sage.

Cirkinoglu, A., & Demirci, N. (2007). Correlation between university students' kinematic achievement and learning styles. *AIP Conference Proceedings, 899*(1), 485-486. doi:10.1063/1.2733248

Clandinin, D. J., & Connelly, F. M. (2005). *Narrative inquiry: Experience and story in qualitative research.* San Francisco, CA: Jossey-Bass.

Colannino, N., Hoyt, W., & Murray, A. (2004). Multiple intelligences and lab groups. Retrieved from http://www.nsta.org/

Coleman, M., & Briggs, A. R. (2005). *Research methods in educational leadership and management.* Thousand Oaks, CA: Sage.

Committee on Prospering in the Global Economy of the 21st Century (US), Committee on Science, & Public Policy (US). (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press.

Cook, M. T. (2007). *The effectiveness of constructivist science instructional methods on high school students' motivation* (Doctoral dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. AAI3263446)

Cordero, E., Porter, S., Israel, T., & Brown, M. (2010). Math and science pursuits: A self-efficacy intervention comparison study. *Journal of Assessment*, *18*(4), 362-375. doi:10.1177/1069072710374572

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches.* Thousand Oaks, CA: Sage.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative, and mixed methods approaches.* Thousand Oaks, CA: Sage.

Creswell, J. W. (2013). *Qualitative inquiry & research design: Choosing among five approaches* (3rd ed.). Thousand Oaks, CA: Sage.

Cross, J. (2007). Developing your child's talent in the real world: Dealing with the juxtaposition between ideal and actual gifted education. *Gifted Child Today, 30*(4), 50-55. doi:10.4219/gct-2007-485

Cross, T. (2005). High ability, rural, and poor: Lessons from project aspire and implications for school counselors. *Journal of Secondary Gifted Education, 16*(4), 148-156. Retrieved from http://www.academia.edu

Croteau, J., Fox, W. P., & Varazo, K. (2007). Mathematical modeling of chemical stoichiometry. *PRIMUS, 17*(4), 301-315. doi:10.1080/10511970601134377

Cutolo, A., & Rochford, R. (2007). An analysis of freshmen learning styles and their relationship to academic achievement. *College Quarterly, 10*(2), 1-17. Retrieved from http://www.collegequarterly.ca

Dahsah, C., & Coll, R. (2007). Thai grade 10 and 11 students' conceptual understanding and ability to solve stoichiometry problems. *Research in Science &Technology Education, 25*(2), 227-241. doi:10.1080/02635140701250808

Dahsah, C., & Kruatong, T. (2010). Quantitative chemistry teaching and learning at the high school level: A case study in Thailand. *International Journal of Learning, 17*(9), 45-59. Retrieved from http://ijl.cgpublisher.com

Dani, D., Wan, G., & Henning, J. E. (2010). A case for media literacy in the context of socioscientific issues. *New Horizons in Education, 58*(3), 85-99.

Darling-Hammond, L., & Berry, B. (2006). Highly qualified teachers for all. *Educational Leadership, 64*(3), 14-20. Retrieve from www.googlescholar.com

Darling-Hammond, L., & Sykes, G. (2003). Wanted: A national teacher supply policy for education. *Educational Policy Analysis Archives, 11*(33). Retrieved from http://epaa.asu.edu

Dawson, V. (2007). Factors influencing preservice teachers' decisions to become secondary science and mathematics teachers. *Teaching Science, 53*(4), 28-30. Retrieved from www.questia.com

De Jesus, H., Almeida, P., Teixeira-Dia, J., & Watts, M. (2007). Where learner's questions meet modes of teaching: A study of cases. *Research in Education, 78*(1), 1-20. Retrieved from http://www.eric.ed.gov

Denzin, N. K., & Lincoln, Y. S. (2008). *Strategies of qualitative inquiry*. Thousand Oaks, CA: Sage.

Doerfert, D. (2011). *National research agenda: American Association for Agricultural Education's research priority areas for 2011-2015.* Lubbock: Texas Tech University, Department of Agricultural Education and Communications.

Dollar, D. (2001). Practical approaches to using learning styles in higher education (Book Reviews). *Community College Review, 28*(4), 82. Retrieved from Professional Development Collection database.

Dori, Y. J., & Herscovitz, O. (1999). Question-posing capability as an alternative evaluation method: Analysis of an environmental case study. *Journal of Research in Science Teaching, 36*(4), 411-430. doi:10.1002/(SICI)1098-2736(199904)36:4 <411::AID-TEA2>3.0.CO;2-E

Doughtery, R. C., Bowen, C. W., Berger, T., & Rees, W. (1995). Cooperative learning and enhanced communication: Effects on student performance, retention, and attitudes in general chemistry. *Journal of Chemical Education, 72*(9), 793-798. Retrieved from http:// www.questia.com/

Douglas, O., Burton, K. S., & Reese-Durham, N. (2008). The effects of the multiple intelligence teaching strategy on the academic achievement of eighth grade math students. *Journal of Instructional Psychology, 35*(2), 182-187. Retrieved from http://eric.ed.gov

Dubetz, T., Barreto, J., Dieros, D., Kakareka, J., Brown, D., & Ewald, C. (2008). Multiple pedagogical reforms Implemented in a university science class to address diverse learning styles. *Journal of College Science Teaching, 38*(2), 39-43. Retrieved from http://scholar.google.com

Dunn, K., & Dunn, R. (1993). Learning styles of the multi-culturally diverse. *Emergency Liberian, 20*(4), 24-32. Retrieved from http://eric.ed.gov

Dunn, R., & Dunn, K. (1999). *The complete guide to the learning styles inservice system*. Boston, MA: Allyn & Bacon.

Eaves, M. (2009). Learning styles technology and supporting overseas learners. *Multicultural Education and Technology Journal, 3*(1), 61-73. doi:10.1108/1750 4970910951156

Entwistle, D., & Newble, N. (1986). Learning styles and approaches: Implications for medical education. *Medical Education, 20,* 162-175. doi:10.1111/j.1365-2923.19 86.tb01163.x

Eriba, J. O., &, Sesugh, A. (2006). Gender differences in achievement calculating reacting masses from chemical equations among secondary schools students in Markurdi Metropolis. *Chemistry Education Research and Practice, 1*(6), 170-173.

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education, 42*(3), 255-284. Retrieved from http://www.iste.org

Evans, K. L., & Leinhardt, G. (2008). A cognitive framework for the analysis of online chemistry courses. *Journal of Science Education and Technology, 17*(1), 100-120. doi:10.1007/s10956-007-9087-x

Evans, K. L., Yaron, D., & Leinhardt, G. (2008). Learning stoichiometry: A comparison of text and multimedia formats. *Chemistry Education Research and Practice, 9*(3), 208-218. doi:10.1039/b812409b

Eve, R. (2007). Science education and belief in pseudoscience. *Skeptic*, *13*(3), 14-15. Retrieved from http://eric.ed.gov

Fisher, D., Grant, M., & Frey, N. (2009). Science literacy is strategies. *Clearing House, 82*(4), 183-186. Retrieved from http://www.fisherandfrey.com

Froschauer, L. (2006). Should science be included in adequate yearly progress? *NSTA Reports*. Retrieved from http://www.nsta.org/

Gabel, D. (1999). Improving teaching and learning through chemistry education research a look at the future. *Journal of Chemical Education, 76*(10), 548-554. doi:10.1021/ed076p548

Gale, M. T. (2011). *Gameplay in higher education: The use of serious games vs traditional instructional methods in learning* (Doctoral dissertation). Retrieved from http://etd.auburn.edu

Gardner, H. (1993). *Multiple intelligences: The theory in practice.* New York, NY: Basic Books.

Gardner, H. (2004). *Multiple intelligences: New horizons.* New York, NY: Basic Books.

Gregorc, A. (1979). Learning/teaching styles: Potent forces behind them. *Educational Leadership, 36*(4), 234-236. Retrieved from http://googlecholar.com.com

Groff, L., Smoker, P., & Co-Directors, G. O. (2009). Introduction to future studies. Retrieved from http://itari.in

Guiso, L., Monte, F., Sapienza, P., & Zingales, L. (2008). Culture, gender, and math. *Science, 320,* 1-23. doi:10.1126/science.1154094

Gullatt, D. E. (2008). Enhancing student learning through arts integration: Implications for the profession. *High School Journal, 91*(4), 12-25. Retrieved from http://muse.jhu.edu

Guzey, S. S., & Roehrig, G. H. (2009). Teaching science with technology: Case studies of science teachers' development of technological pedagogical content knowledge (TPCK). *Contemporary Issues in Technology and Teacher Education, 9*(1), 25-45. Retrieved from http://www.editlib.org

Guzzetti, B. J., & Bang, E. (2011). The Influence of literacy-based science instruction on adolescents' interest, participation, and achievement in science. *Literacy Research and Instruction, 50,* 44-67. doi:10.1080/19388070903447774

Haidar, A., & Al Naqabi, A. (2008). Emiratii high school students' understanding of stoichiometry and the influence of metacognition on their understanding. *Research in Science & Technological Education, 26*(2), 215-237. Retrieved from http://www.ingentaconnect.com

Hammond, L., & McCloskey, L. (2008). Assessment for learning around the world: What would it mean to be internationally competitive? *Phi Delta Kappan, 90*(4), 263-265. Retrieved from http://www.kappanmagazine.org/

Hand, B., Yang, O., & Brusvoort, C. (2007). Using writing to learn science strategies to improve Year 11 students' understanding of stoichiometry. *International journal of Science and Mathematics Education, 5*(1), 125-143. doi:10.1007151763-005-9028-1

Harris, K., & Farrell, K. (2007). The science shortfall: An analysis of the shortage of suitably qualified science teachers in Australian schools and the policy implications for universities. *Journal of Higher Education Policy and Management,* 29(2), 159-171. Retrieved from http://www.cshe.unimelb.edu

Haskell, D. H., & Champion, T. D. (2008). Instructional strategies and learning preferences at a historically black university. *Journal of Negro Education, 77*(3), 271-279. Retrieved from http://www.jstor.org

Hatch, J. A. (2002). *Doing qualitative research in education settings*. Albany: SUNY Press.

Hawk, T. F., & Shah, A. J. (2007). Using learning style instruments to enhance student learning. *Decision Sciences Journal of Innovative Education, 5*(1), 1-19. doi:10.1111/j.1540-4609.2007.00125x

Hechinger, J. (2011). Majority of U. S. students lack proficiency in science, national test shows. Retrieved from http://www.bloomberg.com

Herron, J., Frank, D., Sarquis, J., Sarquis, M., Schrader, C., & Kukla, D. (1996). *Heath chemistry.* Lexington, MA: D. C. Heath and Company.

Hirsch, E. D., Jr. (2010). *The schools we need: And why we don't have them*. Retrieved from books.google.com

Hodson, D. (2011). *Looking to the future*. Springer, The Netherlands: Sense.

Hoffmann, R., & McGuire, S. Y. (2010). Learning and teaching strategies. *American Scientist, 98*(5), 378-382.

Holbrook, J. (2009).The meaning of scientific literacy. *International Journal of Environmental & Science Education, 3*(3), 275-288. Retrieved from http://www.ijese.com

Holdren, J. P. (2008). Science and technology for sustainable well-being. *Science, 319*(5862), 424-434. doi:10.1126/science.1153386

Holliday, T. L., & Said, S. H. (2008). Psychophysiological measures of learning comfort: Study groups' learning styles and pulse changes. *Learning Assistance Review, 13*(1), 7-16. Retrieved from http://www.eric.ed.gov

Hudson, S. (1996). Science teacher supply in the United States. *School Science and Mathematics, 96*(3), 133-140. doi:10.1111/j.1949-8594.1996.tb15827.x

Huann-Shyang, L., Sung, T., & Treagust, D. (2005). Chemistry teachers' estimations of their students' learning achievement. *Journal of Chemical Education, 82*(10), 1565-1569. Retrieved from http://academic.research.microsoft.com

Hwang, W. Y., Chen, N. S., Shadiev, R., & Li, J. S. (2011). Effects of reviewing annotations and homework solutions on math learning achievement. *British Journal of Educational Technology, 42*(6), 1016-1028.

Jackson, R. R. (2009). *Never work harder than your students and other principles of great teaching*. Alexandria, VA: ASCD.

Jacob, B. (2007). The challenges of staffing urban schools with effective teachers. *Future of Children, 17*(1), 129-153. doi:10.1353/foc.2007.0005

Jarrett, D. (2009). Inquiry strategies for science and mathematics learning. *Colección Digital Eudoxus, 2*(7). Retrieved from http://cimm.ucr.ac.cr/

Jeon, K., Huffman, D., & Noh, T. (2005). The effects of thinking aloud pair problem solving on high school students' chemistry problem-solving performance and verbal interactions. *Journal of Chemical Education, 82*(10), 1558-1564. Retrieved from www.eric.ed.gov

Josselson, R. (2007). The ethical attitude in narrative research: Principles and practicalities. In D. J. Clandinin (Ed.), *Handbook of narrative inquiry* (pp. 537-566). Thousand Oaks, CA: Sage.

Kamarulzaman, W. (2012). High achiever's learning style: A case study of a student on the president's list at a public university. Retrieved from papers.ssm.com

Kanter, D. E., & Konstantopoulos, S. (2010). The impact of a project-based science curriculum on minority student achievement, attitudes, and careers: The effects of teacher content and pedagogical content knowledge and inquiry-based practices. *Science Education, 94*(5), 855-887. doi:10.1002/sce20391

Kaya, S. (2008). *The effects of student-level and classroom – level factors on elementary students' science achievement in five countries* (Doctoral dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. 3348503)

Kazembe, T. (2010). Combining lectures with cooperative learning strategies to enhance learning of natural products chemistry. *Chemistry, 19*(2), 1-13. Retrieved from http://khimiya.org

Kazu, I. Y. (2009). The effect of learning styles on education and the teaching process. *Journal of Social Sciences, 5*(2), 85-94. Retrieved from http://perweb.firat.edu

Keengwe, J., OnChwari, G., & OnChwari, J. (2009). Technology and student learning: Towards a learner-centered teaching model. *AACE Journal, 17*(1), 11-22.

Kekelis, L., & Gomes, L. (2009). Bridging the engineering workforce gap through community outreach. *Journal of American Waterworks Association, 101*(8), 52-59. Retrieved from http://www.awwa.org

Kolb, A., & Kolb, D. A. (2012). Kolb's Learning Styles. In *Encyclopedia of the sciences of learning* (pp. 1698-1703). New York, NY: Springer.

Lan, O. S., & Tan, M. (2008). Mathematics and science in English: Teachers' experience inside the classroom. *Jurnal Pendidik dan Pendidikan, 23,* 141-150. Retrieved from http://usm.my

Levesque, K., Wun, J., & Green, C. (2010). Science achievement and occupational career/technical education coursetaking in high school: The class of 2005 (NCES 2010-02). Retrieved from http://nces.ed.gov

Lincoln, F., & Rademacher, B. (2006). Learning styles of ESL students in community colleges. *Community College Journal of Research & Practice, 30*(5/6), 485-500. doi:10.1080/10668920500207965

Liu, X. (2009). Beyond science literacy: Science and the public. *International Journal of Environmental & Science Education, 4*(3), 301-311. Retrieved from http://www.ijese.com/IJESE_v4n3_Special_Issue_Lui.pdf

Loucks-Horsley, S., & Matsumoto, C. (1999). Research on professional development for teachers of mathematics and science: The state of the scene. *School Science and Mathematics, 99,* 258-271. doi:10.1111/j.1949-8594.1999.tb17484.x

Loxley, P. M. (2009). Evaluation of three primary teachers' approaches to teaching scientific concepts in persuasive ways. *International Journal of Science Education, 31*(12), 1607-1629.

Luft, J. A., Wong, S. S., & Semken, S. (2011). Rethinking recruitment: The comprehensive and strategic recruitment of secondary science teachers. *Journal of Science Teacher Education, 22*(5), 459-474. http://dx.doi.org/10.1007/s10972-011-9243-2

Lyons, T. (2006). The Puzzle of failing enrolments in physics and chemistry courses. *Research in Science Education, 36*(3), 285-311. doi:10.1007/s11165-005-90

Maltese, A. V., & Tai, R. H. (2010). Eyeballs in the fridge: Sources of early interest in science. *International Journal of Science Education, 32*(5), 669-685. doi:10.1080/09500690902792385

Maltese, A. V., & Tai, R. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. *Science Education*, *95*(5), 877-907. doi:10.1002/sve.20441

Matthews, K. E., Adams, P., & Goos, M. (2009). Putting it into perspective: mathematics in the undergraduate science curriculum. *International Journal of Mathematical Education in Science and Technology, 40*(7), 891-902. doi:10.1080/0020739090 3199244

Merriam, S. B. (1988). *Case study research in education: A qualitative approach*. San Francisco, CA: Jossey-Bass.

Merriam, S. B. (2002). *Qualitative research in practice: Examples for discussion and analysis*. San Francisco, CA: Jossey-Bass.

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation: Revised and expanded from qualitative research and case study applications in education.* San Francisco, CA: Jossey-Bass.

Michigan Department of Education. (n.d.). Michigan merit curriculum: Course/credit requirements - Chemistry. Retrieved from www.michigan.gov

Mitchell, G. R. (Ed.). (1997). *America's new deficit: The shortage of information technology workers*. Darby, PA: DIANE.

Myers, R., Oldham, K., & Tocci, S. (2000). *Holt chemistry.* New York, NY: Holt, Rinehart, and Winston.

National Science Teachers Association. (2007). Teaching science in the twenty-first century: The science and mathematics teacher shortage fact and myth. Retrieved from http://www.nsta.org/

Obama, B. (2009). State of the Union address. Retrieved from www.whitehouse.gov/

Obande, M. (2003). Sex differences in the study of stoichiometry among secondary school students in Makurdi, local government. *An Unpublished PGDE Project BSU Makurdi.*

Oblinger, J. (2006). Ensuring students' success. *Educase Review, 41*(3), 10. Retrieved from http://net.educause.edu/ir/library/pdf/erm0635.pdf

Ohio Department of Education. (2012). Criteria for graduating with honors for the graduating class of 2012 and beyond FAQ. Retrieved from http://education.ohio.gov/

Okanlawon, A. E. (2010). Teaching reaction stoichiometry: Exploring and acknowledging Nigeria Chemistry teachers' pedagogical content knowledge. *Cypriot Journal of Educational Sciences*, *5*(2), 107-129. Retrieved from http://www.world-education-center.org/

Oskay, O., Erdem, E., Akkoyunlu, B., & Ytlmaz, A. (2010). Prospective chemistry teachers' learning styles and learning preferences. *Procedia Social and Behavioral Sciences, 2*(2), 1362-1367. doi:10.1016/j.sbspro.2010.03.201

Otero, V. K., & Harlow, D. B. (2009). Getting started in qualitative physics education research. *Reviews in PER, 2*. Retrieved from education.ucsb.edu

Owens, T. (2009). Improving science achievement through changes in education policy. *Science Educator, 18*(2), 49-55. Retrieved from http://www.eric.ed.gov

Ozdemir, P., Guneysu, S., & Tekkaya, C. (2006). Enhancing learning through multiple intelligences. *Journal of Biological Education, 40*(2), 74-78. Retrieved from www.eric.ed.gov

Ozdener, N., & Ozcoban, T. (2004, May). A project based learning model's effectiveness on computer courses and multiple intelligences theory. *Educational Sciences: Theory & Practice, 4*(1), 176-180. Retrieved from http://www.academia.edu

Paideya, V. (2010). Exploring the use of supplemental instruction: Supporting deep understanding and higher-order thinking in chemistry. *South African Journal of Higher Education, 24*(5), 758-770. Retrieved from http://www.sabinet.co

Pedretti, L. A. (2010). *The effects of inquiry-based activities on attitudes and conceptual understanding of stoichiometric problem solving in high school chemistry* (Unpublished doctoral dissertation). University of Wisconsin-Stout, Menomonie.

Peterson, E. R., Rayner, S. G., & Armstrong, S. J. (2009). Researching the psychology of cognitive style and learning style: Is there really a future? *Learning and Individual Differences, 19*(4), 518-523. doi:10.1016/jlindf2009.06.003

Petrilli, M., & Scull, J. (2011). *American achievement in international perspective.* Washington, DC: Thomas B. Fordham Institute.

Prabhu, M. (2009). Obama launches STEM initiatives. Retrieved from http://www. eschoolnews.com

Prakash, D., & Klotz, A. (2007). Should we discard the “qualitative” versus “quantitative” distinction? *International Studies Review, 9*(4), 753-754. doi:10.1111/j.1468-2486.2007.00744.x

President’s Council of Advisors on Science and Technology. (2010). *Prepare and inspire: K-12 Education in science, technology, engineering, and math (STEM) for America’s future.* Retrieved from http:www.whitehouse.gov

Prugsamatz, R. (2010). Factors that influence organization learning sustainability in non-profit organizations. *Learning Organization*, *17*(3), 243-267. Retrieved from http:// emeraldinsight.com

Reio, T. (2006). An examination of the factor structure and construct validity of the Gregorc style delineator. *Educational and Psychological Measurement, 66*(3), 489-501. doi:10.1177/0013164405282459

Romanelli, F., Bird, E., & Ryan, M. (2009). Learning styles: A review of theory, application, and best practices. *American Journal of Pharmaceutical Education, 73*(1), 1-5. Retrieved from http://www.ncbi.nlm.nih.gov

Roseman, J., & Koppal, M. (2008). Using national standards to improve k-8 science curriculum materials. *Elementary School Journal*, *109*(2), 104-122. Retrieved from http://mitep.mspnet.org

Ruthven, K. (2011). Using international study series and meta-analytic research syntheses to scope pedagogical development aimed at improving student attitudes and achievement in school mathematics and science. *International Journal of Science and Mathematics and Science, 9*(2), 419-458. doi:10.1007/s10763-010-9243-2

Salamah, A., & Schwartz, M. (2007). Students' understanding of conservation of matter, Stoichiometry and balancing equations in Indonesia. *International Journal of Science Education, 29*(13), 1679-1702. doi:10.1080/09500690601089927

Sampson, D., Karagiannidis, C., & Kinshuk, D. G. (2010). Personalized learning: Educational, technological and standardization perspective. *Digital Education Review, 4,* 24-39. Retrieved from http://www.ub.es/multimedia/

Selman, V., Selman, R. C., Selman, J., & Selman, E. (2011). The natural way to learn: Learn without "learning." *Journal of College Teaching & Learning, 2*(10). Retrieved from http://scholar.google.com/

Sendlinger, S. C., DeCoste, D. J., Dunning, T. H., Dummitt, D. A., Jakobsson, E., Mattson, D. R., & Wiziecki, E. N. (2008). Transforming chemistry education through computational science. *Computing in Science & Engineering, 10*(5), 34-39. Retrieved from http://ieeexplore.ieee.org

Shore, R. (2009). PreK-3rd: Teacher quality matters (PreK-3rd Policy to Action Brief, 3). Retrieved from leadershiplinc.illinoisstate.edu

Siedman, I. (2006). *Interviewing as qualitative research* (3rd ed.). New York, NY: Teachers College Press.

Sinkovics, R. R., Penz, E., & Ghauri, P. N. (2008). Enhancing the trustworthiness of qualitative research in international business. *Management International Review, 48*(6), 689-713. doi:10.1007/s11575-008-0103-z

Skelton, P., Seevers, B., Dormody, T. & Hodnett, F. (2012). A conceptual process model for improving youth science comprehension. *Journal of Extension, 50*(3). Retrieved from http://www.joe.org

Smart, K. L., & Csapo, N. (2007). Learning by doing: Engaging students through learner-centered activities. *Business Communication Quarterly, 70*(4), 451-457.

Stake, R. (1995). *The art of case study research.* Thousand Oaks, CA: Sage.

Sternberg, R. J., & Grigorenko, E. L. (2004). Successful intelligence in the classroom. *Theory Into Practice, 43*(4), 274-280.

Stiles, K. E., Mundry, S., Hewson, P. W., Loucks-Horsley, S., & Love, N. (2009). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin Press.

Stine, D. D., & Matthews, C. M. (2009). The U.S. science and technology workforce. Retrieved from http://digitalcommons.ilr.cornell.edu

Strengthening high school chemistry education through teacher outreach programs. (2009). Retrieved from http://www.nap.edu/

Sturgis, P., & Allum, N. (2004). Science in society: Re-evaluating the deficit model of public attitudes. *Public understanding of science, 13*(1), 55-74. doi:10.1177/0963 662504042690

Taskin-Can, B. (2011). The perceptions of pre-service science teachers concerning constructivist perceptive to teaching. *Journal of Baltic Science Education, 10*(4), 219-228. Retrieved from http://indexcopernicus.com

Tomlinson, C. (2005). This issue: Differentiated instruction. *Theory Into Practice, 44*(3), 183-184. doi:10.1207/s15430421tip4403_1

Ucak, E., bag, H., & Usak, M. (2006). Enhancing learning through multiple intelligence in elementary science education. *Journal of Baltic Science Education, 26*(2), 39. Retrieved from http://www.indexcopernicus.com

Uce, M. (2009). Teaching the mole concept using a conceptual change method at college level. *Education, 129*(4), 683-691. Retrieved from http://www.eric.ed.gov

Vaino, K. (2009). Identifying chemistry teachers' beliefs. *Science Educational International, 20*(1/2), 32-43. Retrieved from http://files.eric.ed.gov/fulltext/ EJ890654.pdf

Viadero, D. (2005). Panel urges U.S. to push to raise math, science achievement *Education Week, 25*(8), 6. Retrieve from http://www.edweek.org

Wang, K., Wang, T., Wang, W., & Huang, S. (2006). Learning styles and formative assessment strategy: enhancing student achievement in web-based learning. *Journal of Computer Assisted Learning, 22*(3), 207-217. Retrieved from http://eric.ed.gov

Watanabe, M., Nunes, N., Mebane, S., Scalise, K., & Claesgens, J. (2007). Chemistry for all, instead of chemistry just for the elite: Lessons learned from detracted chemistry classrooms. *Science Education, 91*(5), 683-709. doi:10.1002/sce.20213

Watters, D., & Watters, J. (2007). Approaches to Learning by students in the biological sciences: Implications for teaching. *International Journal of Science Education, 2*(1), 19-43. doi:10.1080/09500690600621282

Wehrwein, E. A., Lujan, H. L., & DiCarlo, S. E. (2007). Gender differences in learning style preferences among undergraduate physiology students. *Advances in Physiology Education, 31*(2), 153-157.

Wener, P., & Woodgate, R. L. (2013). Use of a qualitative methodological scaffolding process to design robust interprofessional studies. *Journal of Interprofessional Care, 27*(4), 305-312. doi:10.3109/13561820.2013.763775

Wilson, M. L. (2012). Learning styles, instructional strategies, and the question of matching: A literature review. *International Journal of Education, 4*(3), 67-87. Retrieved from www.macrolink.org

Wisniewski, M. A. (2010). Leadership and the millennials: Transforming today's technological teens into tomorrow's leaders. *Journal of Leadership Education, 9*(1), 53-68. Retrieved from www.fhsu.edu

Wu, S., & Alrabah, S. (2009). A cross-cultural study of Taiwanese and Kuwaiti EFL students' learning styles and multiple intelligences. *Innovations in Education & Teaching International, 46*(4), 393-403. doi:10.1080/14703290903301826

Yuenyong, C., & Narjaikaew, P. (2009). Scientific literacy and Thailand science education. *International Journal of Environmental and Science Education, 4*(3), 335-349. Retrieved from http://www.ijese.com

Zumdahl, S. (2002). *Chemistry.* Boston, MA: Houghton Mifflin.

Appendix A: Interview Questions

1. Tell me about your experiences teaching stoichiometry.
2. How do you present the concept of stoichiometry to students?
3. Describe the students' reactions to this concept.
4. What methods do you use to introduce the stoichiometry? (e.g., inquiry, demo, hands on, experiments, lecture, activity)
5. When do you present the concept of stoichiometry during the chemistry course?
6. How do you ensure that the objectives for teaching stoichiometry are being met?
7. What barriers do you feel are preventing the students from understanding and mastering concepts associated with stoichiometry?
8. What are strategies that you use to help students understand and master concepts associated with stoichiometry? (e.g., papers, handouts, experiments, tutoring, classroom discussion, demonstrations)
9. What instructional methods were not useful in teaching the concepts associated with stoichiometry?
10. What types of technology are used when teaching stoichiometry?
11. What methods do you use to assess students' understanding and mastery of concepts associated with stoichiometry?

Appendix B: Transcribed Responses to Interview Questions

Teacher 1

In my experience teaching stoichiometry used to be very, very difficult task to teach. I call it an emotional loop. It has become easier over the years but never easy.

In presenting the concept, generally we start our conversation about the mole. We start out with conversations about converting things that they're familiar with. So how, for example, one egg can quickly become a whole bunch of molecules of so and so while one person two hands, two hands to two hands and two feet, two hands and two feet to ten fingers and ten toes, how you can have a conversation about one particular thing, how those numbers can become exponentially larger.

The initial response of the students is stress. They are stressed out. I think I am doing better now because I've learned to start out with conversations about things that they're more familiar with. The mole is an unimaginable number and so I think taking the mystery away from it, I'm getting a little better, like for example I have them adopt a paper for a minute and we talk about the number of dots that they can make in a minute and I try to discourage them from listening to the person next to them on how they make your dots so that is not synchronized so they can see how quickly one minute or how much you can do in one minute and we go from there I had them to do conversions. Taking a mole of pennies and calculating the number of dollars that that is how hard it is. When you put dollar signs in front of it, then they really get it because we talk about what will happen if you won a big game.

Where your place value would be with respect to winning the big game? And how much you will win if it were in pennies and you want a mole of pennies how many dollars that would be, how many place values so they could understand that you know it's really, really good news to win big game but if you want a mole of pennies that is we've taken a fortunes of some of the richest people in the world and try to convert those to how many moles they have and so once that decimal point starts getting way to the left of their value for people that we know are rich, then they can understand you know that concept a little more.

One of the methods I use is an activity involving dotting for a minute. Sometimes I do a demonstration. I may go to the scale and take a penny, there’s 2.5 grams and they convert that to the number of moles that that is. Familiarizing them with how you can quickly go from 2.5 grams all the way down to some ridiculous number. They really, I think they get used to scientific notation without appreciating what it really is until they see the value for a mole. I make them write out numerically in standard notation what 6.02×10^{23} is and I, that's all that piece of paper so that it's always startling to them as they're going through their notes to go back to their piece of paper so that they understand, this number is not anything to play with.

They're always very intimidated when they see that because we are just use to maybe at the most going to, we say a million, we're pretty much done and when we say a billion, we're certainly done and once we start getting pass billions and they're still going and going and going and so you can see the appreciation for the number for real as the conversation progresses.

I usually present the concept in two places, one is before balancing equations and the reason is just so that when we start talking about the mole, they've had exposure to what the meaning of a coefficient is. But we don't go into it in any depth. I may take 6.02×10^{23} and say, one mole of water. And then I make sure an equation one mole of water and then I'll say 6.02×10^{23} times two moles of water so that they can see, you know, just the progression of what's going to happen to the equation with not necessarily knowing what a mole is. But just to get them accustomed to when we balance equations is not a two for two sale. It's when we say, two moles of is two of this big number so you need to understand the things that you're putting in that test tube and how it's not we only say two grams of this because have the concept of mass in two grams. But the size of the atoms and the number of the atoms that are actually reactant or not is really unimaginable.

So, beyond that, there is a much gone until right after balancing equations. So we do molar mass some things like that.

I introduce the concept after balancing equations. Just but there's no real conversion with it. I just want them to see that as we're balancing equations because they get caught up in if this coefficient of two somewhere there he is they think OK s there's two atoms. They don't understand that when I say for every time I say one mole of these, I am adding a factor of 6.02×10^{23}. So it isn't a lot of I just want them to have an appreciation for what they've done because they get caught up and when we say there's two on the left versus two on the right we mean a whole lot more of that but this is just the grouping that we're talking about.

I ensure the objectives are being met by giving quizzes. We have a lot of quick quizzes and really when I say a lot of quick quizzes I mean almost daily on that. Where it say there's one conversion that they have to do before they come in. The same conversion they have to do before they leave if they got it wrong. If they got It right then they get another one to do before they leave so kids have a tendency of waiting for the storm to be over so a lot of times they're not mastering the skill because they know it will be over soon. That one is never over soon and so really getting them to appreciate the fact that this is the crux of the matter and until we get to gas laws or no not even there. That's it, you know what I mean and it really have an appreciation for the fact that this will never be over. You have to learn stoichiometry.

For all intents and purposes is the culminating activity for a kid that's just a basic chemistry and it is the beginning of the activity for kid that is going on to a higher level chemistry. There are some other line items that we touch on after stoichiometry but for the most part is that one thing that I can almost say beyond the shadow of a doubt if the key gets this they are the best chemistry students for that particular level. And if they don't get it, it is because they have been where they needed to be at every point because stoichiometry is the one that hones every skill that you ever try to teach in one particular act.

I give oral quizzes. Some of the oral quizzes just have to do with me reading the question to them and then figuring it through as I’m reading. When I first give oral quizzes, I try to lead them toward a certain behavior with the inflection at my voice. If they really listen to how I'm speaking even if they don't know what to do. I'm kind of speaking in a manner that leads you to know what to do next. And then you know as time goes on it's less than inflection to give you an hints on what to do I just speak the problem and I sit in here supposed to be able to go.

One of the barriers preventing the students from understanding I think is the fear factor. I think the word itself is a very intimidating word. It sounds hard. Because of that it's very hard to demystify it so we have to really be careful how we approach it. I think by starting out with dimensional analysis without talking about any chemistry goes a long way because those behaviors of cross counseling. If they really, really get that skill, when we start talking just in terms of chemistry you may not know anything else but you do know that grams on the top has to cancel the grams on the bottom and the next set of parenthesis and so, introducing the idea of dimensional analysis and really, really making sure that they get that skill it goes along way because the kids that don't ever learn what they need to be with respect to stoichiometry is because they never got that dimensional analysis down pass to when we're using dimensional analysis to learn things that are very familiar to them.

They don't get that. De dat, de dat, de dat, de dat, de dat, de dat, they don't get that and so when we start putting things in those parenthesis, they really aren’t familiar to them because they don't understand the rhythm of dimensional analysis. Cross canceling it still doesn't mean anything because they don't have anything to draw upon, they don't remember when they say seconds to seconds, hours to hours, days to days, so really teaching them how to translate units that you are very familiar with into units that you may not be familiar with that to me is the biggest challenge, you know, just really demystifying that skill and it's funny because when they get it they tend to laugh because they can't believe how hard it was and you hear stuff like, "That's it?!"

You know that's always funny how frustrated they get when it's not hard to them anymore. You know any constant repeat of practice because it's hard for everybody. It's hard getting across what you see so clearly. Where I really do try to remember when I learned it and that helps a lot.

I use a variety of strategies to help the students understand. I think that but the one thing that I really above everything else, I try to do a lab as it relates to that skill. As many as I can, I try to push the idea of actual yield versus theoretical yield. What it is and were actually doing in the class how it relates to the stoichiometry given just an abundance of exposure to it because part of it is, they don't receive it initially because they are so afraid and they have to have more experiences with getting it right than a whole lot of other skills.

Like I said you know, that can be a grueling process for everybody because you know, I have probably about hundred, 500 hundred and six maybe even more than that. Stoichiometry problems and most things that you may have a whole bunch of problems you really don't need that many. They get it. Stoichiometry you’re going to use every problem that you and you still going to have to borrow some from a colleague because they need that much exposure.

The instructional method that did not work was the sequencing. I don't think because of the sequencing that we use, I don't think that there's anything that they don't use. I think that once we get on other side we start going on nuclear things like that you know there's ton of waste, you know things that you can do without it but stoichiometry from math to dimensional analysis, to formula writing to balancing equations to stoichiometry it uses every single skill from the beginning of the school year till were almost out of here

I think jumping into the problem is the instructional method that did not work for me. When I say jump and now you know, putting a problem on the, I give you a perfect example. When we do guess, you know you put the formula up on the board and you scan the problem this the first pressure, this is the second pressure so it's very, very clear what to do because if there are six variables for the combo and you've label five of them then you can pick out if you have no P then you can use the formula with the Ps so it's very, very obvious. I think stoichiometry you can't attack it like that. You have to work with them in terms of interpreting.

I think methods that don't allow kids an appreciation for getting the balanced equation first, doesn't work. So many kids can see what the product is. I don't know, with me, let me just say it like this. When I learned stoichiometry it was very difficult for me to learn stoichiometry because my teacher just did the problem. He just did the problem and he did the problem so much so and I didn't understand so much so until I spent most of my evenings in renaissance high school until 7 to 8 o'clock at night. But he still did the problem so for the benefit that I receive for staying so long after school I didn't get anything. It wasn't until I started really teaching it, that I understood that kids can't see the equation in the words.

So a kid that can't see the equation in words, they cannot even begin to figure out what it is that they're looking for because they don't know what the equation is. If you can't get the equation out of it then you know as some it is just constantly used in the vocabulary. Well if it saying what is the product, then the answer to your question is on the right side of the equation. So now we need to sort where this is or what is formed. This is what is formed. The answer to that question can't be on the left side, it has to be on the right side. So I think while I can't say to what doesn't work, I'll say what does work is constantly modeling how to just get the equation. because many other kids can't learn stoichiometry not because of stoich- they don't know where to start.

So it's like OK you have 8 grams of this and 9 grams of this so how much of this can be produced but if they don't understand that I just gave you two reactants. They're not going to be able to predict the product. Or if they think that I just gave them two products, it's over. So really, really working with massaging the way that the question is asked. Because once you pull out that equation then you can label your heir and you can label your beer and you can go right in to your grams and 8 moles of 8 moles of 8 moles so it flows like that.

Barriers that prevent kids understanding. Kids that can't understand, well I mean even those that are afraid, part of the reason why they are afraid is still it all to me it still goes back to dimensional analysis. Dimensional analysis is that's the foundation of skill. I think one of the things that is done in the earlier grades that's to a lot of students detriment is that they are allowed to multiply their way to the answer. And it's very hard for you to re-program a child whose gotten the right answer all these years by multiplying their way to the answer. Now you want to change that behavior and that's very hard. I think pushing dimensional analysis, that's why I am glad that we spend a lot of time with that because that skill does not come through these doors.

And if it did some of the problems that I see even in some of the upper division science classes, they would not be that way. Just really getting them to understand that you really are not multiplying your way through stuff, you're converting. Getting down to really behave in terms of converting as opposed to multiplying until you just pass out, when you do that and you give the kid a big red C, for a skill that is for all intensive purposes so elementary. Then you continue to do that it's very, very hard to get them to think up. You know and I think you know, and they do have, they have the ability to learn it. They have the ability to learn it. But you need to take time to do that.

I think because of the way that I do the test and quizzes from polyatomic ions, the majority of them are ready to learn it. But the diligence that is going to take to learn it, they don't want to do that. I think layering the test and quizzes is a really good idea and the reason is because they are intimidated when you give them 50 charges. So grouping them in terms of five parts give them five negatives and layering it like that it gives them number 1, it gives them time to master the foundation of work and the other thing that it does is it lets them know that there is something coming.

That we're not just doing this type of stuff just to do this type of stuff. There is something coming that's going to require to build that foundation so I think that most of them, if they stay on test and charge diet, if they stick to their charge's diet, then they are ready. But if they don't stick to it, then you know, this is not ready. I think that any evil way that I find that one of the reasons why I do it like that is for two reasons, number 1 they need to be ready but Number two, our kids get tired of flunking and so they may not learn the first five and they may not learn the first ten but by the time they understand, that every five school days there's going to be an assessment attached to what you the least that you could have done.

By the time we get to that fourth quiz then it surprise me. You know like, uh oh I am not flunking this again and so then they start. And always give them an opportunity if they have flunked the first 5, and they passed the first 10 then I'll remove the F from the first five. Because I am not going to keep punishing you. You know because that's a reflection on your average. I want to make sure that if you do what I tell you to do, I am not going to hold you hostage to that. But they are just some day just want to it doesn't matter. I'm going to catch as many as I can. If they get 80 on the first ten, then they'll get an 80 o the first five and the first ten because technically that's the same material. If they get, a 100 or the first 15 then they will get a 100 of the first five and the first ten. So every week they do have an opportunity for redemption.

Most of them, they catch on to that. And reality is by the time we get to the chemistry, that's really when I need them to know that answer they're not miss on anything academically by not learning their charges other than just stressing themselves out unnecessarily so you know.

The technology we use virtual labs, They have the clickers, but the virtual labs I like because you can show very, very quickly atoms, molecules, multiplying and dividing it. Re-shifting for products, you can take away all that you're trying to explain with a wonderful simulation and so you know and if there's a learn for the most part and so anytime you can show a pitcher that's a thousand words that I don't have to say. They bring in things, they make models, they do posterboard presentations, and so it allows them an opportunity to see things more than one way.

As they become more fluent in chemistry, they can go back to their old projects and so I think I have that right? Can I tweak it? Turn it back in. I guess more points and most of the time they say yes. If it is clear to me like sometime we have kids that do a really, really good job on their presentation because the chemistry is not there, it’s wrong. But the effort was put forth to do a good job, they just didn't have the tool kit enough to be able to articulate that. As you put more and more in their toolbox then they're able to spot their own errors, so when they are able to spot their own errors, they won't make those again. You know they get a whole lot more value out of finding their own stuff. Then the comments that you put on their page.

The methods I use to assess students understanding are presentations and they do a lot like I said they do a lot of quick quizzes, first five minutes, last five minutes, they do a lot of that. They do a lot of pure teaching. I will put a group of problems and basically what it is like lets' say I have 20 problem OK? I will cut it into threes and three problems on this table, three problems on this table, so every table has three problems and they are responsible for working those problems out correctly and then present it. And when they present it isn't the matter of being right or wrong, as you're presenting but the students in the classroom should be able to help you, if you end up with grams squared, we're clearly done some wrong. You know and so what it does is it allows the students to experience 3-0 stoichiometry problems without the one off guard.

They learn to backtrack. They can point to where they went wrong. If there's a problem calculating molar mass they'll see it as opposed, even if they don't the mass as you go , I will call out what the masses are for each of the atoms and they can't type it into their calculator just to check their molar masses. I find that I love the book for their periodic table but sometimes, If I'm trying to hurry up I don't have time for you to be trying to find variant. OK I'll just call it out or I'll use things that are very, very common so that they're not perusing. I find if I use carbon dioxide that goes a whole lot further then aluminum cyanide. You know they just , because they also use on time so I try to do as much as I can with representative problems you just cover more ground like that.

Teacher 2

My experiences teaching stoichiometry has been difficult. It is a concept that is a little farfetched for the student to achieve, and I usually have some difficulty with it unless he is an advanced chem major.

I present the concept by following the book. We use Holt Chemistry, and I usually introduce it after balancing equations. The students who seem to grasp it is usually the student like I said before who was more advanced. If I had more time like if I had an advanced camp, I probably would be more successful.

When I first introduce the concept they are interested; but after few days of it, they lose interest because they just don’t seem to grasp it right away. I tried different supplements. I asked them to look it up as much as they can using other ancillary materials and things. We come back to class, they still just don't have that interest level.

Initially I use the textbook. Next will be any chemistry site online. I tried there a number of them. I try to start out with the most minimal. I have even resorted back to a general science book, and that seems to be of an introductory phase for them because some students are introduced it in general science, perhaps 8th, 9th grade, and that really does make the difference.

I usually present the concept in the spring of the year, so that's usually after … second semester.

I make sure the objectives are being met basically by testing, evaluation. Most of the evaluations are written

The only barrier I think would be is the fact that they were not exposed to it in a previous science course. I think if all of them were introduced to it in a previous science course, may be even in 8th grade, then they would have some familiarity with it. It wouldn't be so foreign because for some students, it's just a foreign subject to them; and at that time of year, they are no longer interested in grasping something like that.

I also think their mathematic ability is a barrier. They need to be very comfortable. Just like in any chemistry class, they need to be very comfortable in their mathematical ability. They need to be confident learners, and they have to be eager. It's a certain type of student that really wants to grasp it. I believe I gave a student the option, I'm sure some would opt out. Just a lot of the girls that I've taught, it was like teaching auto-mechanics or something. That was just something that they just opted, wanted to opt out. They did not want to that after so long, they just … I had to come with something else that would bring their interest level back.

I try to incorporating many strategies to help students understand stoichiometry, and then I ask them to resort to technology also. I can't think of the website right now that explains it well, but I think it's Jefferson Labs. I think they have a good demonstration of it, and a lot of students seem to enjoy that one better. I find it more self-explanatory than the others with Jefferson Labs.

I find just using the book alone is not a good instructional strategy. You can't deal with just the textbook. You have to go out. You have to go out of your … think outside of that particular box. You have to grab your resources, ancillary materials, and things like that to enhance it.

I use technology in my classroom frequently. I use everything. I try to utilize everything that comes with Holt Chemistry as much as possible. If there's anything else I can look up at the time, I will utilize. There are number of websites, Chemistry.com, Jefferson Labs. I just can't think off most the top of my head. I utilize as much as I can for them based on what I googled at the time. It seems to help, but I usually try to go back like I said as far as in general. It seems to give them a better … more of an introductory type phase for it. If I go back where it's like this, the sake of general science, we have one in here.

I can probably take you to the chapter, and it would introduce it in a much better form for them. I think the language is more … is watered down a little bit instead of like the college prep type thing, and they seem to grasp it better that way. If you have general science …

I do only one stoichiometry lab. We tried in the very beginning, and not much more than one. It's only the one that's in under Holt Chemistry, the very first one. After that, that's pretty much it because I don't have an advance chemistry class, so there is not a big need for it, so we just move on.

The method for assessing students understanding this year is going to be different. There are tests that are designed that I will utilize by the district. I'll utilize those pre-impulse tests, and we'll take it from there. That will be a major test, and I'm happy about that because it is predesigned by the district. It measures how much they should have utilized or achieved within the timeframe. However, There isn't much stoichiometry is on the no more than four questions.

I am on track with the district pacing chart. I would say so because this is the second semester. Yes. Definitely in second semester, not until second semester.

In closing, I hope that I have been some help for you. If I … I'll be sure to take a peek at the questions that are designed by the district and just as a brainstorming thing tonight. I'll take a look at that, and see exactly how much in detail it goes into. From what I understood, before it was only about four questions. It varies from time to time. It varies, it changes.

Teacher 3

In teaching stoichiometry, I try to take it stepwise; but even with taking it stepwise, the students are still unable to put all the pieces together once we get to doing multistep equations where they have to go from grams to moles, and from moles to amount of another substance, and then to grams with a new substance. I find myself going back to the basics, and giving them stepwise questions, and also stopping and … Let's start over. I'd love that.

I present this concept of stoichiometry. I basically take it stepwise, and teach one portion at a time going from grams to moles and moles to grams of the substances. On day two, I teach going from grams to moles, and then to atoms of the … or particles of the compound. Then, I move into another chapter where we're going to use the mole ratio and going from grams of one substance to moles of the new substance, and then from grams of one substance to grams of the new substance.

The students are receptive after I introduced it. I have actually just taught the moles conversion. In the beginning,; but a lot of times since I've taught moles to grams and grams to moles, and then from moles to atoms, from atoms to moles, they continue to try to use the atoms, Avogadro's number because it's one of the simpler things where it's a cost, and it's always the same. I find that they're trying to slide that conversion factor up into our equation when it's not needed.

When I first introduce the concept, I typically do lecture and problem-solving, and then move into actual activities where I'm actually going to have them calculate how many grams of a substance they make. There's a stoichiometry lab in the whole textbook that I use on page 786 where we actually calculate how many moles were in the solution.

I also introduce molarity with that lab which reinforces why they would need to use this to figure out how many grams would actually go into the solution to make the solution, and actually from that, how many moles of the substance should be able to be pulled on.

I technically teach stoichiometry after I've done chemical reactions which also follows ionic bonding, covalent bonding. They now roll into the chemical reactions that go back and teach atoms to moles at that point, moles to atoms, and then we get into stoichiometry.

To ensure that the objectives are being met, I give them one of the multistep problems where they have to convert from moles of one substance to moles of the new substance, and then go a step further by starting with grams of one substance, and being able to calculate how many grams of the new substance from the chemical reaction they would be able to make.

Being able to see it(stoichiometry) in action is a barrier I think. When it comes to the lab, it seems though you need to teach lab in four hem, but in the calculations, you can actually teach the lab with the calculations which is what I did for molarity. I didn't really introduced molarity until we needed to know the molarity of the solution for the lab calculations. If there was a way to actually teach stoichiometry using the lab before doing or while doing lab, it would be great; but so much goes into this concept of stoichiometry. In order not to lose the students, I normally teach it first, and then reinforce it with the lab, and show them how it's used in doing the calculations for predicting how much product they make.

Then, I discuss how it would be used in a laboratory setting where someone wanted to make 50 grams of some certain substance. In order to do that, they have to work in reverse to figure out how much was needed as the starting materials.

The strategy I use most to help understanding is tutoring. It would be the most helpful. Going back with students are having a disconnect. I was having them try the problems, and then coming to the point where I see where they're struggling. I found that the mole ratio, when I taught mole ratio, I taught it, and we looked at several different mole ratios. Just identifying the different mole ratios from the problem helped with that.

It seemed to be a lot easier that you're at the new cast of taking a whole day and just teaching mole ratio, giving them 10 equations, and having them set up all the mole ratios that could be made from that one equation, so that that became evident.
Then, we went back to actually calculating from grams to moles and moles to grams. Taking it stepwise and teaching each concept over the course of a week, each new step was a new day, and just getting them to master that calculation, and figuring out what they need, they instill what they're given was added success this year.

Tutoring really helped, and piece-wise, just making it piece-wise. This piece and then this piece to trying to teach that whole concept all at one time.

In thinking back, I can't really say what instructional methods weren't successful. I do not know of any instructional method that did not work. Pretty much, I just had to go over it several different times. Teaching it in the beginning, it just didn't … Every student didn't get it on the first try; but in going around to see what was going on, I used the toolkits that were in the textbook which had a roadmap which showed them. It was a graphic organizer that worked, but what didn't work, I didn't really employ enough strategies to say, "Well, this didn't work over this." The way I decided to teach it pretty much worked for those who were able to grasp the concept. I found that the same students who had problem doing metric conversions in beginning of the year because they were not strong as math students, we're not able to grasp this concept as well.
The strategies that were employed were successful in teaching the concept. The only thing I found that wasn't … didn't plan out the way it should have was I used the … Textbook had a handout where the first page had a practice problem, and they converted from grams to mole. Then, the second practice problem was going from grams of one substance to moles of another substance. Next page was going … because there were four sample problems in all to show each step along the way. I just found that in going back to that and using that as reinforcement after the students have mastered it, I found that some of them fail short before finishing the packet.

There were 16 questions in all. Out of that 16, the majority of them got through the first eight. With the last eight after the repetition, they just fell off. Maybe that was it, just employing the reinforcement of, “Now, we’re going to do it. Go back and do each step along the way before doing the total problems, stoichiometry of grams to grams.”

I use a variety of technologies to teach this concept. Over head, Power Points, visual concepts from the Power Points. I’ve also used a gizmo that was found at ExploreLearning.com which has the students to … That’s where I came and tried to solidify it with the students who did not grasp the concept on paper. We did an interactive activity, and it seemed to help them where they were given the conversion factor. In order to use it, the set up gave them where if it was grams and grams, they ended up with $grams^2$ to let them know that the units did not cancel, and that they needed to flip the conversion factor which did help in seeing how the conversion factor, how the units in the conversion factor makes the difference in what’s going on with the problem.
That was a method that I didn’t plan, interactive on online simulation of calculating it for the students who were unable to figure out what the actual conversion factor should’ve been, how it should’ve been set up. They were already set up, and all I have to do is insert them, and then click them to flip the tile if it needed to be changed for the units to cancel. That brought home the fact that the units need to be a certain way to cancel for my lower level learners.

I Pretty much just use showing calculations as a means for checking understanding, however my tests are set up to be multiple-choice questions. In doing that, the students still have to show their work, so they show their understanding of how they got to this answer. They’re able to check their answer once they calculate the problem and look at the answer choices given.

In closing I would like to add students this year, they are exploring learning. They get a chance to see actual simulations on stoichiometry. I would probably introduce it once I found the first day that the students were struggling with how to put the conversion factors in and how to identify them. I would actually pull that on the first to second day as opposed to … I use that as reinforcement all the way for going back for the learners who did not grasp the concept in beginning. I will probably use it earlier in my teaching.

Teacher 4

As a matter of fact this is perfect because I just taught it. I just finished the assessment yesterday. I gave them an assessment yesterday. It was a disaster.

A few of my students scored high on the test and I was really, really excited about that. It made me feel like, "Oh somebody got it." Because at first I felt like nobody's getting this. But the basic problem is the kids' math skills and then the whole idea of the multi-step process which, the multi-step process is part of the critical thinking skills. So that is a huge issue, the kids just, they don't make the connection and so what I did was I started by teaching molar math so we got that down. And then we went from molar math to, I think we've done empirical formulas first or vice versa something like that. Then I had the balanced equations, we worked on balancing equations and then after we finished the balancing equations then we started the stoichiometry. We started by first just doing one-step process.

OK. We have grams let's get, if we have grams we trend grams/mole, if we have moles we trend from moles/grams. That whole little piece in the middle and I thought I was doing a fairly good job in giving them a step by step process. But of course they follow it when I'm doing it, but the minute I said, "OK now you do it", it just doesn't work. What I did this time and I'll be happy to share it with you, but I gave them a short study guide where we practiced all the little steps and then I gave them the test the next day. I let them take it home. We worked it out in class. I allowed them to take it home and then do the work. Then when they get it, they freeze up. Of course I have a Woodrow Wilson fellow with me this year and he said, "Mrs. Bali you shouldn't have called it a test." He said, "Maybe if you said a quiz or assessment that would have worked." He said, "The fact that you said test might have made them freeze up." But just the whole idea of them working.

Well when I first introduce the concept of stoichiometry, I start with recipes so I have the kids, you know if you have, I think I have like 5 to 6 different recipes and they chose a recipe and they worked in pair, in groups of twos or threes and then they have to decide if I had this recipe how can I make, let's say the recipe call for 8 servings, what do

I need to do to give 20 servings? So I started there and they had a difficult time with that. They had a really hard time but after awhile, they were like, "Oh you don't know I get it".

That was our first, that was our introduction. I did that and that was a segue way into now you can apply them to chemistry if you try to make something you have to change the proportion and how do you do that?

Just like any other science concept, when I introduced the concept of stoichiometry , it was new and so they were like, "Oh my God!", you know. They were "Ah my God!" But I think they were sort of open to it but it's like what do you call it, unfamiliar territory? So they didn't know what they were stepping into, so you know.

I use a variety of methods to introduce stoichiometry. I have to use all of it. But I have to say that with stoichiometry, it is a little bit heavy on the calculations because how else can you get around it? We have one activity where, I can't think of what it was I did but, where, let me see it real quickly. Anyway it will come to me and I'll share it with you, but the kids they didn't get it so I had to go back and try to think of another way to present it to them. But I use all of them, I have to use inquiry base. I have to use, and one other thing I want to say, from day one, I use dimensional analysis, from day one. One thing I want to say too is kids are really, really lazy about writing units down and because they don't write the units down they can't cancel them and they get stuck and so vocabulary is a big thing as one kid on the, let me just show you the question.

OK. This question says, it says what mass of ammonia is formed when 2.8 grams of H2 reacts with excess N2. The students have a difficult time with the vocabulary or even understanding the question. The excess N2 threw the student off. Excess N2 threw the child off and so she was dealing with the 2.8 grams of H2 but then when she went to the step where she had the mole ratio, she put H2 and then N2 on the bottom and so she was like, totally messed up the rest of it. She got caught up there but anyway, what I find is that students like to do hands-on activity but I explain to them it has to mean something and you have to be able to interpret what you did. It can't just be 'oh we had fun, we did this and that', what did you do? What does this mean? How does this relate to what we're learning about in stoichiometry?

The students did a pre-lab and then I made sure the pre-lab was very, very similar to the actual lab that they would do. But it helps some students but it didn't help a lot of students and then the other thing too is when I give them the pre-lab to take home, they don't do it, so that's the big issue too. If they would do it and come back and say, "Oh Mrs. I'm stuck on this. I didn't get pass this point." Then we can work through that but when you just tell it's too difficult and that was their attitude once they got it the introduction the question you're asking, and the introduction it was like OK. This is a big word, stoichiometry, what is it? But once they got into it, it was I think they kind of shut down and say this is too much, I can't do this.

Well as you can see this is now April, and we are just finishing stoichiometry, so this is pretty much towards the end of the school year. We only have 6 more weeks of school, 6-7 more weeks of school, so towards the end, when I feel like they are comfortable and confident with the terminology, that's when I do it.

I usually do it after balancing equations and [inaudible 00:09:43]

I make sure the objectives of the concept are being met by giving them the objectives at the beginning of the lesson. I make sure the students understand what they are being taught every day. Then at the end I assess them so if I assess them then I can tell whether they've met the objectives or not.

As we mentioned earlier, I try to [inaudible 00:10:23] the assessment so when they do the activities for example, if they can't do the activity or if they're sitting there dependent on someone who is getting it to show them then I know that's an assessment in itself. I know the kids doesn't have it.

I see many barriers that prevent the students understanding. Well first and foremost, math concepts. Then for the population that I teach, reading is also an issue for a lot of students. Vocabulary is a huge, huge issue and I'm starting a, as a matter of fact when we were in the workshop, a quiz bee, a couple of weeks ago, the presenter gave us an idea that we try and we're doing it. We're working the vocabulary into word parts so that kids get the prefixes and the scientific prefixes and suffixes and try to decipher and decode those words. So that seems to be working better than what we used to do because we used to the dimensional analysis model and it wasn't working, the kids will just say, "Oh it's too much. I'm not going to do it." So math, reading and like I said, the next big thing I think is the whole idea of this multi-step process.

The critical thinking going from one step to the next, to the next, to the next, they get lost in that somewhere. But if I could only reinforce, and I do it every day, drilling them with metric units, following through with a unit and then you know like just a basic number sets, are you able to look at the number and tell that if I have a large number on top and a smaller number in the bottom, my numbers going to be greater than 1 or vice versa, the number's going to be less than 1. Just those minimal things that they should have had way back in elementary and middle school, you know we spend so much time with that when this is the concept.

Right, well I use a combination of strategies to master the concept and the kids know that I will work with them one on one, I'll work with them in small groups and kids know if they don't get it, they come to me and say, they need to get it, I'll stay on that. If the kid wants to learn, I'm willing to work with that kid. One of my students he's actually receiving specialized services but he came to me it was a week ago and he sat right there in that chair and he said, "Mrs. I did not get this lesson today", and I said, "Let me know the problem. You sit here let's do this." and he sat there, at this smartboard, we're going over this stuff and he said, "Oh, I get it now, that's what you're doing." He don't get the whole thing but he get the molar math and he got the concept of, OK now I have the molar math let me go from moles to grams or grams to moles. They give that up.

So I was happy. I was happy with, "Oh we got this, maybe you know tomorrow we're going to add another step." So I try to break it down into smaller steps and then go back and piece it together because once they have like a, once they have a whole problem, it becomes overwhelming to them. That's because it's just too many, it's just too many steps, you know.

Depending on the book does not work for me. Well for sure, and I'm really not like a book person, I don't usually give my kids open this to this book, you can't do that in chemistry anyway, it's not wise. So I would say, handouts are helpful but not really, because you still have to instruct so giving a lot of independent work is not good. If you give it a small child, like if I give one or two problems, that will work. But, and then even with the lab work, the kids like it but I don't know, I can't say that I can't do it or I won't do it, but I do need to try to figure out something else to help to reinforce the whole idea of stoichiometry and maybe you can help me with some ideas.

I use some technology in the concept of stoichiometry. I use my smartboard every day. I definitely have to use, the interactive smartboard. I definitely have to use and then giving kids and writing it in you know, especially the shy ones. I like to pick on them, I need you to just come up and just stand there giving them that confidence and just getting them to actually rant, that's helpful. The kids are stuck on the concept of moles and number of atoms and so I have to use the atomic model and so like for example, N2, how many atoms do we have? You know, this is 2, how many molecules? One molecule. How many moles? This is one mole. So that whole idea of getting them to do that so- what's the questions again because I [inaudible 00:17:02]?

Oh types of technology. Right. And then also we you know I'll give them a couple of online assignments too. There's a good one that I used to fun-based learning for balancing equations and getting them to just see the models, see the molecules as models so if I have 2CO2 I have actually two Carbons and I have 4 oxygens. Basically, that's it for technology, I haven't used any probes or anything like that.

In assessing students understanding, of course I give the traditional test. But the assessment I like is mostly is I like to use the last to see if they've gotten it. I am toying with the idea of maybe trying to do a project but I haven't figured out how to do that yet and one of the main reasons now, this will work better at your school, because a big problem for me is attendance, so if I kids in groups, Jojo is here today but Susie isn't here tomorrow, so that's not fair to the kids who are who were here every day. So that makes it difficult to put them in groups and that's my drawback in trying to do a project so if I could find a way to do an individual project then I'll do that. And maybe even like going back to the introduction, maybe the introduction part with doing something with the recipes or something having them do something at home, you know something where their dealing with massaging this information as opposed to just hearing it in a classroom or looking on-

In closing, I would like to say to my elementary colleagues to work hard at preparing our kids before they come to high school and say, and you know I'm not trying to pass the buck but there's only so much that we can do in that time frame that we have to do it in and I got to a point where it was like, OK did they get the basic concept of stoichiometry? If they have then I have to move on. As matter of fact we just today started solutions. I just introduced solutions today. So we just ended with the assessment yesterday and then with [inaudible 00:20:28], if we can do that I think if we can get the kids ready with the math and get them used to meaningful way to use vocabulary, scientific vocabulary and not just write down the definition, that doesn't mean anything to a child.

If we can have a way to do that and so the other thing too and I didn't mention as assessment, in the assessment, if they can articulate what they've done in writing and I try to do that maybe once a month or so but the reason I can't do it a lot is because it takes so long. I'm talking about a real meaningful writing. Of course they have to do it after they do a lab and I have fight with them about that. So you know just our basics, reading, writing and math. If we can get that done.

Teacher 5

Initially, when I explain what stoichiometry is the students are, "Well, we can do this." They're kind of confident, but once we get into stoichiometry, they think it's a nightmare. They think it's a monster that is haunting them. They say, "How long must we read on this? Can we skip this? Can we go to something else? Can we go back to the easy stuff." They think they'll identify their worst chapter that they've been through so far. "Why can't we go back to that?" Towards the middle, they are at a point where they almost wanted to give up.

One thing I have done in presenting stoichiometry is, I tell them to find a recipe to one of their favorite meals. What I need you to do is write down the recipe. Then I want you to write down everything you're going buy at the store to make that recipe. They're planning their little meal, and I explain it to them. Everybody figured out what they need to buy. I said, "Now, I want you to identify everything that you need to produce this as a product or produce your lasagna." I have to kind of use other terms of the product reactants to begin with. Then I would say, "You want to make this one pan. How much does it require of this, this, and this to make it?" They're explaining their recipes, and I have them exchange their recipes between the two.

First of all, I attack it with something they love, food. We all can relate to food. After that, everybody's made their pan of lasagna or their cake and everything. "So what do we got now?" "How much did it take for it?" I said, "How much you think you got left?" It make take a little time to do that. I try to make it a big thing, and then they can see it. Therefore, what if I say that those noodles are part of a reactant. Then we identify it, and then use the term product and relate everything through, and they're like, "I like this. I get this." And even then I say, "What's left?" "Well this is left." So I say, "So you can make another pan of lasagna," and they're like, "Yeah." "So how many can you make?" So they try to make as many of their recipes with what they have.

I say, "When you've run out of sauce, raise your hand." They were like, "Oh." I said, "What did you do?" "Well, I ran out of this." I said, this is considered your limiting reagent. Good job! So you can't make any more. You're limited because of that one spaghetti sauce, which is one, really. You can't make anymore product because of that. So that's extra, right? That's your excess. We kind of do that. I like to do the cookie recipe. I try to introduce that, and they kind of, "I like this, I like this." Well, let's relate it to it. That's how I hook them in, but once we get into the middle of it, it kind of changes. They say, let's go back to the recipes.

Generally some are scared when I introduce stoichiometry. But what is stoichiometry? We talk about what it is, and what's the concept, and everything referring to chemistry comes down to this. When we talk about this, I say, every product that you use comes from stoichiometry. Because it's how you put it together to make this. Some of their reactions are good. The ones who have been, that C or better students would be.

Now, my students who are not doing that well, at this point, they are ready to just shut down. I'm almost losing them, and I'm trying to find things to get them back up into the game. If you have students who are D/F students at this time, they're almost, they basically have given up at this point. When they see stoichiometry, they are so scared beyond the point, where they may even sit there, and pretend that they're taking notes, or listening to you, and they absolutely, you're gone, shut you down. You might pick them up at another chapter, but they completely tune you out.

When do you know that? Do you know that when they're nodding their heads? I have kids who are nodding their heads, and I know, they have no clue what you talking about. I'm just nodding my head, so just don't bother me. That's evident in a lab I'll do with stoichiometry. Well, where's all this coming from? I'll gave you that. "Well I didn't get any of it, Miss teacher". So why didn't you tell me this? Why didn't you stop me, or why don't you come after school? At that point they were ready to give up.

I use hands on activities and experiments to introduce the concept. Like I said, we do the recipe. We go back, I review concepts. I review some of the concepts in pieces. Another thing is I have this activity to ... I have made just the units. I have taken a units, like is it mole to mole relationship? Is it mole to gram, which is mole to mass? I put them on index cards, and tape them to popsicle sticks.

What I did is when we're about to go from grams ... say you want to know the volume of something, of a substance. It could be sodium chloride. I'm starting with sodium, as far as I have to know my grams, so I have to get there. What relationship would we go from there? So you have sodium, but you can't go to sodium chloride, because they're two different substances. We know we're going to need a mole/mole, but what do we start with? We have to go from grams to moles. So what relationship are we looking for. They hold up the card that says, 'mole to mass.' Okay, mole to mass, does everybody got that? Okay, we got mole to mass, so we know where we're going.

I used the term road maps. So let's make a road map. I said, "We'll try to get there, so let's do our road map." So they say, "Mole to mass." I said, let's not even look at the numbers. I said, we got to know the units, how we going to get there? And then I said, let's write this down. We do that. Okay, so now we have moles. I said, we're at moles at sodium, and we're still trying to get to that sodium chloride. I said, what relationship do we now? How we going to go? They hold up the card that says 'mole to mole.' I'm like, I can see who doesn't have, mole to mole, up.

So that's what we're doing, and that helped, too. They kind of like that. And I think they like having the cards. That helped out, and that was a way to trigger me to see if everybody kind of working on it. Because I can't see what you're writing, so I had to figure out, what are they thinking over there. [inaudible 00:08:36] and write it big on their little popsicle sticks. So they had a stack of them, so they had to go through what they go through. Everybody think through, when you ready, put your card up, and turn it towards me, not towards your friend. That way we made it through.

I determine when to do stoichiometry by following the pacing chart. I also combined my solutions a little bit with the stoichiometry. It was some things that you talk about making this aqueous solution in this and this and this. So I kind of pulled that in. It's in spring, so according to the pacing chart. I kind of pulled that in at the same time.

I usually present stoichiometry after equations. Because I kind of combine those. I teach equations earlier, probably, than some people because our textbook, and even our pacing chart. You introduce some things, and you just introduce them, but you jump to something else. That's how our textbook is set up. Therefore, if it's coming out my mouth, I teach it then. So they've got a little stoichiometry a little at a time. I used that term. Also, I didn't wait to get to the stoichiometry chapter, or the unit to do that. I used that term when, round the semester, because that's the hardest concept, so I kind of wanted them to hear it, and not just break down and scream, which they have in the past.

Because I'm like, okay, is my pacing chart, I got to do this and this, and then I introduce stoichiometry, but what I've been trying to do is, [inaudible 00:10:56] we going to get to stoichiometry, and this is where all this is going to be put together. We going to have fun, and I'm trying to brainwash them a little bit and prepare them, and wait till they go just 'bam!' The last 2 years, I've been trying so many different things. I think this year, I'm actually getting as further than I ever have with the little tricks I'm doing.

It seems like it's working because it's a brainwashing thing. I don't want to say, it's the hardest thing we ever going to do and this and this. But I've been kind of introducing it throughout the year, at least bring it in term, which is where we're eventually going to get. This is going to be the funnest thing and dah, dah, because you know, they'll listen to previous students from previous years.

In order to make sure the objectives are being met, what I've done is I found the simplest lab that I could find on this planet. I gave each group different numbers, so there's not like they're going to cheat or look it up. It's not something you can look up. I also ask them to write a flow chart from it. Using the flow chart, I know what path they're brain is going on and the concepts, or the conversions or how I'm going to get there. They have to explain to me in words how to get there, but I found the simplest lab, that teaches stoichiometry. You need me to explain the lab?

One of the strategies I use to help students master the concept is first we have classroom discussions. Like I said, I use the recipe to begin with, but also I the simplest lab. What I have them do is I have these pitchers and I fill it with water, and I put them in the freezer so I have this ice cold water. I just give them Styrofoam cups. We're going to drink water today. So I have them mass the cup, and come get this ice water. They get their ice water, and I explain to them, for their first part of their, the mass the cup, and their job is to take three sips of water. I say, you took three sips of water. Mass your cup again. They know how to subtract out and get the maths. I said, you should tell me the number of molecules of water you have.

It's good. I said, okay. Take five sips now. Now tell me how many atoms you have. Take two more sips. Tell me how many [formulas 00:14:12] you used, you have. I'll I asked you to do is drink water. That what I tell them. All I asked you to do is drink water for this lab . So from there, even though the same concept of more from molecules, atoms, and formulas, involves Avogadro's number, it's how to use it, you know, a drink of water, mole of mass of water, is showing you what to do with something that we all encounter every day of our lives. Therefore, all I ask you to drink water.

That's huge. That's huge. And anyone can do that lab. Who doesn't have cups and water. All you need is a balance. I came up with that lab years ago because I didn't have anything. My god. My thing is we may not have anything. So I'm asked to come up with activities and things, where I don't have anything, and that works, and even my kids who didn't get it a couple of times, they get that. They can see it in pieces, so that kind of helps them. They actually like that lab.

One of the instructional methods I did not find useful was the internet. The internet. Our kids love to go to the internet and find thing out. I told them over the years, the internet, everything on the internet is not correct. Because I tell students that bring me stuff, and I always ask them ... it's a plus or minus for the internet. That minuses, everything is not correct, and they'll come up, well, I have to consult the internet. Show me their site, and I'll ... Where the internet is a big plus for me because I like games. Over the years, I have two pages of sources that I check every year for games on how to write formulas, and matching and all of that. I said, what the kids are more into doing their research to help to find how to do things. I always have them send me the link, so I can see if they're explaining it correctly.

Another thing that, I think the internet was that [inaudible 00:16:58] videotaping with their phones or with their tablets were good because they had to give me demos, and they have to explain things to me. Sometimes they can come after school and set it up, and if they can stand in front of me, and explain how to do a problem, Send it to me, I can look at it, and I can use that as a grade. So that means that they was able to pick their problem and be able to go through it on their own pace, and get the ins and outs about it, and understand, and then explain it to me. I use that as a little quiz grade, and they like that. They had fun with that.

In using technology to teach stoichiometry I have to add Well, the internet does work at some point, and the YouTube, some of the YouTube videos. I tell them, everybody send me one, they got to send me a YouTube video that they found that is interesting. I use that for extra credit. They could actually send me the video, but I had to see if it was okay, if it explained it okay. Then I said, you can write that up for a little summary. I'm trying to force them not to just use the book, or sit in class but to go beyond the classroom, and then find something. Do the research, and find something they can use since they want to, because they up on social media. They're really not. They're not. They want to Facebook, and they want to go to that type of social media, but they don't know how to use the other things that's available to them. That's one of the things.

I do have a smart board. I do go, and show them something on as far as certain sites and things, and what they can use. I do do that. But I think as far as, especially stoichiometry, I think if they are able to do a lot of it on their own more so than me finding. They say, "Ooh, I found this really good one." Okay, let's pull that one up, and we look at it, and we might critique that one. Or somebody's explaining something, but we take the sound off of it, and look at what they're doing. So something like that.

I would like to try projects as far as some source for them, but I don't want them get to a source, and copy and paste it. I think if you're standing, I have to hear it, I have to see you doing it, because I don't believe, with technology, they're copy, the plagiarism is off the chart. Therefore, even if you sat down, and listened to the video, and went over it, that means you're still learning to do it. So I'm okay with that.

To access students understanding, we do some of the practice problems in the book. I make up my, I change a lot of things, Okay, here's a problem, we've done it. I'll change just the number of grams or the number of moles or something, and I want you to do the same problem but using this. We do tests and quizzes but like I said, the videos are good. You can use a video for a quiz grade, because they stood in front of you, and they explained how to do it. I don't think a kid needs to do 50 of the same problem to say they understand it. If you can do this for a quiz, and explain everything to me, and 'how to' steps, and what to do, and explain it to me thoroughly like a script. That's good enough. Then you can move onto the next concept.

In my years of teaching stoichiometry I have noticed there is a difference between boys and girls. Years ago, I would have said, there's no difference, but there is. Because when I taught at another program, I could see my boys, they were more math people. We got to be honest, stoichiometry is math, math, math, math. Even though it's just algebra, it's simple math, to be honest. The boys were more willing to do it, whereas the girls were ... being in an all girls school, I see with them with the boys not being present, the girls are there. They're there with me. They're there. They're answering questions. They're jumping on you. "Show me this. Let me see this."

The girls, I would say, are stars and we don't know it. I think the girls are stars, and we do not recognize it. We have a robotics team or engineering, you see it for the boys. Ooh, it's a male thing, but when the girls are like, oh let's try this. But they have the opportunity, especially from the middle school, up to the high school, they come into themselves, and they are star for them. And I can see the difference. Before, the girls in my class would have been as aggressive, as I see the ones now.

I don’t think math is a barrier, I think that they use it as an excuse, because when you look at ... to pass chemistry, the first semester, the first year of chemistry, is simple algebra. It's simple mathematics. You're not asking them to do cosine, tangent, or anything like that. Now when you give into something, it's a thinking process. I don't think the barrier is mathematics. I think the barrier is thinking. Chemistry asks you to think, not memorize. Chemistry is 98% application, and in order for you to apply something, you have to think. If you don't have the math skills behind it, it makes it worse, but I think that is used as an excuse to not accomplish stoichiometry.