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UNIVERSITY OF CALIFORNIA, SAN DIEGO

Think for Yourself: A Writing-Based Chemistry Curriculum

A Thesis submitted in partial satisfaction of the requirements for the degree

Master of Arts

in

Teaching and Learning (Curriculum Design)

by

John Andrew Morgan

Committee in charge:

Rachel Millstone, Chair

Cheryl Forbes

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2011

The Thesis of John Andrew Morgan is approved and it is acceptable in quality
and form for publication on microfilm and electronically:

Chair

University of California, San Diego

2011

Dedication

In recognition of my wife and kids who continue to support me, listen to my constant ramblings, and understand when dad is just tired.

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ABSTRACT OF THE THESIS

Think for Yourself: A Writing-Based Chemistry Curriculum

by

John Andrew Morgan

Master of Arts in Teaching and Learning (Curriculum Design)

University of California, San Diego, 2011

Rachel Millstone, Chair

Colleges and universities require applicants to have completed chemistry because students develop scientific literacy and critical thinking skills by learning and applying chemistry content. Due to the factual nature of standards assessments, chemistry curriculum is focused on student memorization of facts. As a result, many high school chemistry students are learning chemistry test facts rather than critical thinking skills. Students at Orange County high school, in southern California, participated in a critical thinking chemistry curriculum called *Think for Yourself*. Students learn to think critically by constructing scientific theories and analyzing problem solving methods. Through a conceptual writing activity, implemented in this curriculum, students

constructed scientific theories from common observations by applying their prior knowledge to explaining those observations. Through group and classroom discussions students tested, reaffirmed, and analyzed individual ideas to develop group theories and then scientific theories; applying the scientific method rather than learning about it. I collected conceptual writing and discussion data during the six week implementation and examined the effect of the curriculum on student's scientific literacy development. I analyzed student essays for the use of academic vocabulary and level of conceptual reasoning. Additionally, I analyzed discussions for participation and conceptual change. Collected data supports a development in critical thinking. Students developed their ability to apply prior knowledge to an observation, analyze rationale to adjust ideas and explanations, and derive accurate scientific concepts. Student development in these three areas supports the overall project goal of developing high school student's' ability to think critically by approaching problems scientifically.

Chapter I: Introduction

As a high school chemistry teacher, I constantly learn new methods, come up with new ideas, and try to find more effective ways of teaching material. I commute to work by train, a 40 minute ride, twice a day. I spend this time coming up with new ways to teach material and pride myself on being able to explain concepts in as many ways as it takes for a student to understand the concept. In my seventh year of teaching I asked myself an important question; can I do this because I know my content, or do I know my content because I do this? The hours I have spent breaking down concepts to find new ways of teaching have helped me further understand chemical concepts and their applications. I wanted to create a curriculum that teaches students material by doing the opposite of what I do. I relate concepts *to* common observations and I want students to develop concepts *from* common observations.

While the practice of chemistry seems complex, the origins of theory are simple.

At the beginning of each year I tell my students that chemistry is everywhere.

Further, I tell them they already know everything we are going to cover in the course; my job is just to make them aware of the chemistry in their worlds throughout our study of each chapter. Chemistry is an empirical science, meaning it is a science derived from observation and experimentation.

Chemistry, as a science, was developed to quantify and explain the observations we see every day. Chemical processes have developed soap, water purification systems, the internal combustion engine, polymers for protective gear and clothing, plastics, and many more things that students use daily.

Chemistry is not an easy subject for many students. The content requires the combination of mathematical methods and knowledge of scientific concepts. For many students, this is the first time that math is being applied to observations and theory outside of math class. Students who dislike mathematical word problems often despise scientific problems where there are no words, only laboratory data.

The Think for Yourself (TFY) curriculum, implemented through this study is geared at teaching students about the common observations and experiences they have daily. It was not until I covered a class for another chemistry teacher that I realized the name for curriculum. In covering another class I was in charge of students who were not familiar with my teaching style. As a class of sophomore honors students, I felt they would have little trouble adjusting to my method of teaching. I started the class by asking students what they were covering. One student toward the front responded, "We are going over equilibrium, but nobody gets it." I asked students what they did know about equilibrium. After 30 seconds of blank stares I asked, "Have you ever heard the

word?" Immediately after the group nodded, yes, I asked for a complete or partial definition... anything that associated with the word equilibrium. The student response was, "I don't know. What is it?"

"Think for yourself."

I developed the Think for Yourself curriculum from the frustrations explained above. Students can apply simple chemical principals to explain many observations. The application of chemistry to explain common experience makes chemistry a simplistic science; however, despite the simplicity of chemistry, students continue to express a high level of difficulty with the concepts of the course. To simplify the content in the course I designed a curriculum that focuses the course on everyday experiences and observations. To incorporate the use of common observations with the development of critically thinking students I changed methods from teaching students to questioning students. Further, to hold students accountable and to aid students in internalizing and communicating their thought process I added a writing component to the curriculum.

TFY is an accessible curriculum that requires students to apply chemical concepts to their lives. The incorporation and analysis of everyday observations makes the content accessible to all students. Through the curriculum I use simple, everyday phenomena which are, interesting, and concept driven. The

observations make the curriculum accessible, conversely, analyzing experience and prior knowledge to derive chemical concepts makes the curriculum challenging. Students develop as critical thinkers because, through the process of developing concepts from observations, they are required to apply seemingly abstract principles to the context of their lives. I ask students questions rather than give them answers. I ask students to analyze their prior knowledge and experience.

Chapter II: Assessment of Need in High School Science

Introduction

Assessment drives curriculum and education in the United States today. State and national assessments provide data leading to school and teacher ratings of effectiveness. While scores from these tests do not, in California, effect pay or employment, they are a basis for evaluations, both formal and informal. Therefore, it makes sense that teachers prepare students for these tests by effectively teaching to the standardized tests. Instructional activities promote memorization; chapter tests emulate the standards tests, and quizzes use questions similar to standards tests. Fact based tests promote fact based instruction.

The focus of educational assessment in the United States differs from the focus of educational assessment internationally (Organization for Economic Co-operation and Development, 2007). Testing in the U.S.A. focuses on fact recollection, educational equity, and standardized education. Internationally, standardized assessments focus on conceptual reasoning and critical thinking. While the U.S. government has instituted standardized tests focused on factual, standards based knowledge other countries have focused on conceptual knowledge, reasoning, and application (Organization for Economic Co-operation

and Development, 2007). International testing administrations have built tests that focus on the application and use of knowledge rather than actual fact sets. In the age of unlimited information, through the Internet, international corporations value critical thinking and problem solving rather than fact recall. International test administrators utilize this information in developing assessments (Organization for Economic Co-operation and Development, 2007).

While the changes in standardized testing may be the impetus for changes to curriculum, it is practical that effective curriculum not have a correlation with dropping test scores or student understanding. For this project I have limited the amount of change in the curriculum in hopes that standardized test scores will not drop with the implementation of the new activities associated with the curriculum. Teachers, students, and parents must share a common view of the role of education, one which mandates a shift in ideology of school curriculum. Is the goal of education to solely teach content through concept and fact memorization, or is the goal of education to teach content and develop thought processing through the use of content?

Content, is not only the information covered in a specific course, it is a tool used to teach students skills in all content areas. Teachers answer the question, "What skills can students learn from the course?" and from this, teachers find the focus of the curriculum to develop activities, grading models, quizzes, and tests.

Focus on content knowledge can lead to lectures, repetitive work, and memorization while focus on critical thinking through content knowledge allows access to discussions, explanations, argumentation, and construction of ideas. In both models of curriculum the students learn content; however, the skills learned through each of the curricula are different. One curriculum teaches students to derive explanations from simple ideas, the other curriculum teaches memorization and fact recollection.

The International Picture

Worldwide, students take tests producing results, which researchers then utilize to make comparisons between countries. The goal of researchers is to distinguish which countries prepare, or fail to prepare, their students for future success in the global economy (Organization for Economic Co-operation and Development, 2007). Researchers analyze test results and use the international data from these examinations to guide educational improvements or deficiencies in participating countries. These tests, although serving a similar purpose to national and state tests used in the U.S. and California, are structured in a different manner, with a different focus.

Students participating in international testing provide data for the comparison of methods and effectiveness of the educational systems in cooperating countries. Educational leaders use data from the Programme for

International Student Assessment (PISA) examinations to compare countries with performance in reading, math, and science. These tests, given to samples of fifteen-year-old students in participating countries, provide evidence of educational effectiveness in lower grade levels and the effect of the instruction on student education and development.

PISA researchers use data to analyze scores on the exam and to construct new internationally administered examinations. Aside from analyzing testing data, PISA also uses data from areas outside of education. Using research from economics and industry, PISA administrators incorporate key skills rather than key facts into the tests (Organization for Economic Co-operation and Development, 2007). PISA test architects construct examinations using information and data from markets and job trends in the global economy. Fewer questions are categorized as requiring rote memorization and factual recall; more questions present data to students and require inference and reasoning to answer. The application and understanding questions do not require memorized information, but rather reasoning and use of concept. Exam questions correlate with skills necessary for success in current careers. An analysis of job trends shows a shift from repetitive, manual jobs to dynamic, collaborative jobs. In moving to a more technological world, repetitive tasks are more cost efficient when automated by computer (Levy and Murnane, 2004).

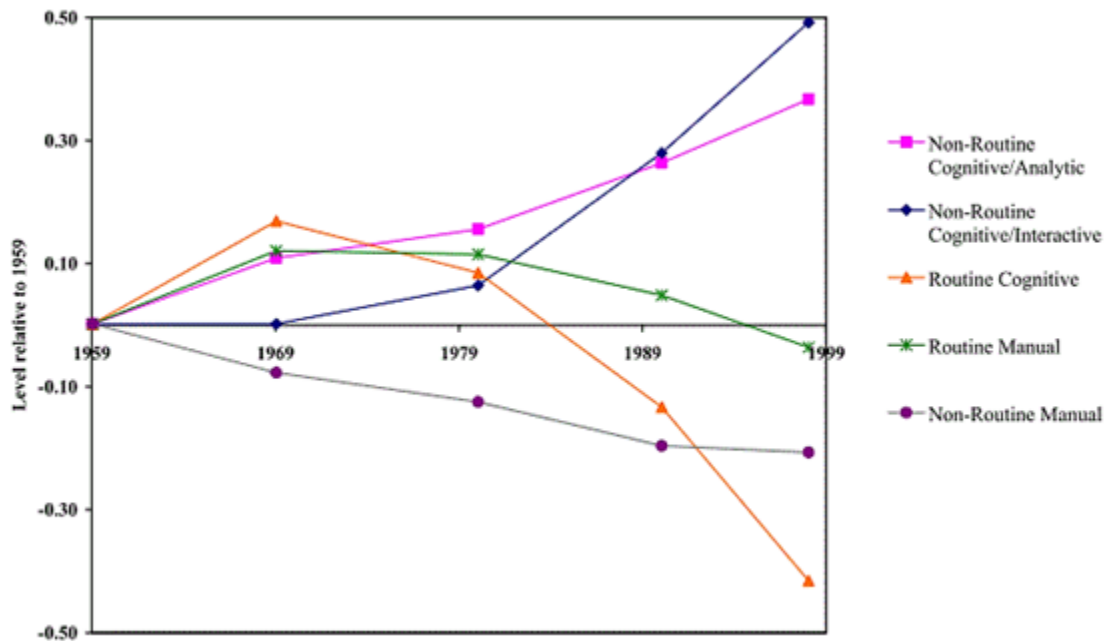


Figure 1: The change of demand for routine and non-routine job types from 1959 to 1998 (Levy and Murnane, 2004).

Figure 1 above illustrates the increase and decrease of available jobs in the United States from the year 1959 through 1998 (Levy and Murnane, 2004). Terms given to the right of the graph describe the task type based on the level of repetition and the level of thinking required to perform the responsibilities of the job. Levy and Murnane classify job descriptions by the repetition and required level of mental processing of the job (2004).

Routine and non-routine tasks refer to the repetitive nature of the work performed. Routine refers to repetitive procedural tasks. Once a worker learns and masters a task, a worker performs the task repeatedly. Conversely, non-

routine refers to tasks that are ever changing. These tasks, although repetitious in conceptual application, are not repetitious in procedure. Jobs involving these tasks require manipulation of procedures to complete individual tasks. From 1959 to 1998, demand in jobs requiring application, manipulation, and collaboration increased, whereas jobs requiring repetition and following a single procedure decreased.

Other task distinctions in figure 1 describe the mental processing required for the task. Levy and Murnane use cognitive/analytical, cognitive/interactive, and manual to describe requirements of job performance (2004).

Cognitive/analytical tasks represent jobs requiring the highest level of thinking. These tasks require workers to think critically and solve multiple problems depending on the specific task and situation to create a product.

Cognitive/interactive tasks have had the greatest increase over the forty-year span of the study. These tasks require high levels of thinking and concept application as well as collaborative group efforts to produce a complex product. Manual tasks refer to low level thinking tasks where the focus is on doing rather than thinking.

PISA assessments are designed to critique the potential of a country based on the test scores of current students. Students are deemed more prepared for jobs of the twenty-first century in content area if they score higher on the

associated exam. From figure 1, non-routine cognitive/interactive tasks have the largest increase over the last half-century, followed by non-routine cognitive/analytic tasks. Employees in non-routine jobs are required to efficiently approach challenging tasks that involve analysis and collaboration. To test the preparedness of students entering the future economy, students answer non-routine, cognitive, analytical, and collaborative questions to a larger degree than routine questions. Assessments have moved from the traditional restatement of fact to the use and application of data. Students are not required to know facts or details as often as they are required to know methods of dealing with information that is both familiar and unfamiliar.

Known facts are limited to specific times when concepts expand the application and use of facts. An example of a fact is the boiling point of water. Water, an integral substance in chemistry, is a necessity for humans, plants, and animals to live making it a focus of cities. Today many foods are prepared through the boiling of water, from potatoes, to pasta, and many of the easily made foods students prepare and eat; therefore, a study of the boiling point of water is not only part of chemical content, but applicable to students. The boiling point gives information regarding temperature indicating a point at which water bubbles and changes from a liquid to a gas. Students in high school chemistry learn that water boils at 100 degrees Celsius. Many students learn this

fact and apply this knowledge when cooking pasta noodles. In reality, water only boils at 100 degrees Celsius when the water is pure and at sea level.

Understanding the concept of boiling is a more useful fact, than the knowledge of a specific boiling point, since students who know and understand boiling can manipulate conditions and control the exact temperature at which water (or other substances?) boils. Students understanding the concept of boiling have insight into the common practice of adding oil or salt to water when cooking pasta and gives rationale for many packaged foods having high altitude cooking instructions. The addition of oil and salt may expedite the times for cooking pasta because a solution of water boils at higher temperatures. In higher altitudes, when water boils at lower temperatures, these additions make cooking faster, or, in some cases, possible.

Two approaches may be applied when teaching the boiling point of water. One, teachers have students memorize the fact. Two, teachers guide students to understand the concept of boiling. The outcomes of instruction are different even though the information is nearly the same. The fact that water boils at 100 degrees Celsius is an aesthetic piece of data. Teaching the concept explains the fact. Students can use concepts to make connections to life and draw relationships between multiple concepts. When explaining the addition of salt or oil to water to cook pasta, teachers guide students to use the concept of

colligative properties, the manipulation of properties through solution concentration. Replacing a fact with a concept provides opportunities for further student learning, understanding, and application.

The results of the most recent test, 2003, are analyzed in the 2007 report by the Organization for Economic Co-operation and Development (OECD). The OECD reports the United States ranked twenty-fifth in mathematics and twenty-first in science worldwide (2007). Despite our pride in being a global leader in innovation, the United States education system is not a global leader in producing innovative students and future industry leaders.

The National Picture

State science standards control the assessment of students in the United States. Individual state standards are similar to one another and state assessments come from the same framework and research. The standards used in the U.S. are based on Trends in International Mathematics and Science Study (TIMSS). TIMSS is the guide for framework and standards in the U.S. (Robitaille, 1993). By extension, it is also the guide for final assessments in the U.S. The standardized final exams assess student knowledge of standards. These standards are facts a student should know after completing a year-long class in a subject.

The implementation of standardized, summative exams is the result of the Nation at Risk report and the legislation of the No Child Left Behind Act (NCLB). The Nation at Risk report, researching a compilation of data internationally, showed U.S. students were scoring below students in other countries (National Commission on Excellence in Education, 1983). Years later, the federal government implemented the NCLB legislation to ensure all students receive adequate instruction and mandated all students would be proficient in required material (McGuinn, 2006). Standardized testing is the measure of accountability in these claims.

In California, as an example, these tests are called California Standards Tests (CST). The state, districts, and schools use the CST scores, reported yearly, to assess the effectiveness of schools and teachers on student learning in a subject. Broken down by age, ethnicity, socioeconomic class, and location, CST data is used as a powerful means of analyzing student progress, informing change in curriculum, and backing reform efforts in individual classrooms, schools, and districts.

Student performance on the CST indicates California performs below the national average on comparable examinations (U.S. Department of Education, 2009). With over half of the students in California scoring at the “below basic” level, changes to the curriculum need to be made (National Center for

Educational Statistics, 2005). This is not a problem limited to a specific ethnicity, socioeconomic class, or location. The numbers represent a statewide average. As a state, California is failing the test. In 2005 and 2009, the National Center for Educational Statistics reported the percentage of students achieving below basic scores on state standardized science tests were 56 percent and 40 percent, respectively.

Although students have the potential to pass these tests, the gap between performance and potential is a great concern. What is causing students to perform below their potential? How are students receiving passing marks in science, then testing below basic in simple knowledge tests? These lengthy state tests are not considered high stakes. For students, there is no motivation to pass and no consequence for failure. Tests are administered in long testing sessions. Tests are fact based and teachers shape instruction around the test by teaching basic, factual knowledge through memorization. Students learning facts in efforts to pass an end of the year exam is neither authentic nor engaging. This type of instruction is based on fact acquisition rather than authentic, useful, and applicable learning, which ultimately promotes the development of citizens who think critically.

Teaching the basic material of a subject has become a necessity. Continually teaching the basics of science in first level science courses does not

engage students. A lack of interest in science courses has reduced the enrollment of students in higher level science courses and science based majors (U.S. Department of Education, 2009). As an industry, chemistry is the most lucrative in the United States, bringing in over five billion dollars per year. Although the number of jobs in chemistry has risen, the number of students majoring in physical sciences has remained constant since 1966 (U.S. Department of Education, 2009). Scientists are hired, high paying jobs are filled, yet, many of these scientists are coming from other countries, as a country, the U.S. is not producing enough qualified scientists to fill these jobs. By altering the curriculum, student engagement will remain constant, increasing student enrollment in advanced science classes and science majors. Non-science-bound high school students, although contributing to a different field, are able to offer better contributions having participated in a course with a high demand for critical thinking and the application of concepts outside the scope of science.

Conclusion of Need

Assessments are used in this paper to point out the expectation placed on students and how this affects interest and success in chemistry. Although there is a need to alter assessments, it is not the goal of this paper. The need of this paper is to alter curriculum to one that closes the gap between potential and achievement by teaching the concepts of science in an engaging, student-

centered approach using high order thinking to connect students to new material.

Student-centered and assessment driven teaching methods are not mutually exclusive. Altering instruction of content standards to focus on the student makes information more relevant to students. The role of the teacher needs to change from that of a lecturer and deliverer of information to that of a guide who channels student thought and learning with concept development and the acquisition of required material. Students experiencing this type of instruction choose to ask pertinent questions and build new knowledge from the internal storehouses of knowledge they already possess. Students are challenged to question their own ideas and reflect on their previous understanding of information. Misconceptions are recognized, challenged, and then altered to a more correct understanding of concepts being taught (Marzano, 1991; Strike and Posner, 1993). The recognition of misconceptions turns misconceptions into useful tools for cognitive development and knowledge acquisition (Smith, diSessa, and Roschelle, J., 1993). A teacher-guided, student-centered approach leads to engaging chemistry courses and maintains a focus on required standards.

The goal of chemistry is not for students to pass a culminating standards exam. Chemistry must be viewed as a course that develops scientific inquiry

methods and understanding as well as the maturation of cognitive and metacognitive strategies. Colleges and universities require chemistry, not because all majors use the knowledge obtained in the course, but because all majors require a level of analytical expertise in breaking down problems and solving them in a systematic manner. Curriculum should focus on helping students develop key problem solving strategies by utilizing content as a tool and context for development. Successful application of this curriculum will lead to student preparedness while maintaining or improving test scores.

Chapter III: Review of Relevant Research

Introduction

Reform has been the topic in education since the Nation at Risk report was published in 1983 (National Commission on Excellence in Education).

Researchers reported that education in the United States was failing to prepare students for college and the workplace. Since the publication of the report, educators, administrators, and politicians have looked to reform education.

Educators now follow similar frameworks, standards for learning, and standardized testing to make material uniform. Although topics are standardized, teachers still have the flexibility to teach these topics as they see fit.

Teachers maintain control in their classrooms over certain variables of instruction. For example, teachers may choose to emphasize individual learning or collaborative work by using various activities, such as writing, discussing, and problem solving, to name a few. Since content, in science, has not changed significantly since the publication of *A Nation at Risk*, researchers have studied various teaching methods to determine best practices for student learning and efficiency.

There are many methods of teaching implemented in classrooms across the world. Researchers have published data in support of different models of teaching and learning that seem to contradict the basic philosophy and structure of learning. Gersten, Keating, and Becker support the use of direct instruction through scripted teaching and response (1988) while Vygotsky supports social learning through collaboration, talk, and negotiation (1986). The direct instruction method moves every student at the same pace, emphasizing rigid learning and language development through defined prompts and responses. Social learning revolves around the premise that learning is not possible without language and talk. Social learning requires flexibility by both the teacher and student to work through unforeseen challenges. Direct instruction and social learning both support best practices; however, best practices in direct instruction are different than best practices in social learning. While these theories conflict in style and approach, the goal remains the same, to maximize student learning. In both approaches success is supported by data, asserting that two, seemingly opposing, theories are correct.

Approaches to teaching are as numerous as there are teacher personalities. Good teachers, fit personality and teaching style to a set of best practices enabling them to have the greatest impact on their students. To name a few traits, teachers can be strict, loud, quiet, humorous, serious, tense, or relaxed.

Each teacher's personality fits a different teaching style. Despite style, teachers with best practice instruction employ common aspects to their teaching.

Common elements of best practice instruction teach students at the appropriate level of difficulty, utilize a student's prior understanding, build relationships among concepts, and continually assess learning progress. Like teaching methods, successful curriculum must utilize best practice commonalities and provide opportunity for practice in underlying goals. For the sake of chemistry, the underlying goals of curriculum are the development of critical thinking and metacognitive awareness of conceptual reasoning.

Curriculum has both content, facts listed in frameworks and standards, and focus, the skills acquired by learning the content. Curriculum must effectively teach the content standards of the course but instruction and curriculum may focus on skill development rather than standards. Examined through this study is the use of writing in a science course. Students learn science content standards through writing, while the focus of the curriculum remains on effective conceptual construction and communication through the writing process. Writing contextualizes and conditions facts by requiring students to understand big ideas and break them down in detail (Rivard, 1994). Focus on a list of facts does not promote understanding of the big picture, or big idea. Larger concepts are more meaningful because of their larger application to

student life, not limited to course content. Constructing new ideas from student experience builds opportunities for constant re-evaluation, rethinking, and revision of ideas (Marzano, 1991). Teaching science through writing and experience ensures an appropriate level of difficulty, utilizes student prior understanding, connects multiple concepts, and continually assesses a student's learning progress. Through this literature review, research will support a curriculum that encompasses science standards, enhances best practice instruction, and focuses on communication and reasoning through writing.

Engagement

Learning for the sake of learning is a hard sell to most students in high school. Aesthetic education does not foster the intrinsic motivation of students (Deci, 1995). Students show less interest in courses that do not apply to them, they are motivated by content related to them (Yamauchi, 2005). Naturally, students come to school with interests and questions. A student-centered course, one in which a student's interests and prior knowledge connect with concepts to answer these questions, connects course content to students.

Connecting to student vocabulary and language is an effective means of accessing student knowledge and connecting student interest. Content vocabulary language is required for successfully communicating understanding of course material. The commonly used speech of students is considered the first

language of any student and, as a result, all academic courses can be taught with many of the same principals as a second language course (Brown and Ryoo, 2007). Brown and Ryoo support the use of separate content language and concept instruction in science classes to teach both the vocabulary language and concepts of course material (2007). Students presented material in everyday vocabulary first showed a significantly larger improvement on test scores than those presented with material in content vocabulary (Brown & Ryoo, 2007). By ignoring the use of content vocabulary teachers present material in unfamiliar language and unnecessarily increase difficulty of material (Bernstein, 2004). Presenting material in academic vocabulary requires students learn the vocabulary and the concept at the same time. By using common vocabulary, students achieve a higher level of success due to the fact that learning is a result of focus on either concept or vocabulary, not both at the same time. Adjusting from an academic vocabulary delivery of content instruction to common student vocabulary leads to increased retention in content acquisition (Brown and Ryoo, 2007).

The argument against the use of student's common vocabulary is the "dumbing-down effect." Teachers in my school argue that teaching in common language decreases rigor resulting in a lack of preparedness for the standards assessments they will face at the end of the course. However, separating course

content into concept and vocabulary instruction makes content and vocabulary more accessible (Brown and Ryoo, 2007). Students learn both concept and vocabulary, but at different times. Concept learning is the material, observations, theories, and laws presented in the course. Vocabulary is the course related terms that ease the communication of concepts. Students learning concepts in their native vocabulary can understand observations and interpret findings. Following concept instruction, students learn the vocabulary behind the concept and communicate to a more intelligible audience. In the 2007 study by Brown and Ryoo, the concept first and vocabulary second approach increased student examination performance significantly more than students taught vocabulary and concept concurrently.

Student vocabulary, like experience, is a source of prior knowledge. Students define science in terms of self when they use their common vocabulary and experience. Students with a self-centered view of science learn more than students learning aesthetically (Taber, 2009). Educators utilizing a student's prior knowledge and current language in instruction make content more authentic and accessible for students (Nersessian, 1999).

Restructuring Knowledge

Students have already experienced most concepts covered in high school chemistry. Most students are unaware that what they know is useful in the

classroom. Presenting common experiences to students connects prior knowledge to the classroom; further discussion connects experience to course content. Teachers must both elicit prior knowledge from their students and challenge student ideas to enhance student learning. Choosing to only access prior knowledge minimally enhances student learning. When used as scaffolding for further knowledge acquisition, the use of prior knowledge is an effective means of approaching new material (Marzano, 1991). Prior knowledge can be categorized, transformed, and restructured into academic language and useful content knowledge. Restructuring knowledge, rather than direct instruction, affects understanding and increases problem solving and reasoning ability (Bransford, Brown, & Cocking, 2000). Scaffolding new information with previous knowledge increases the rate of understanding new concepts and retention new material (Yamauchi, 2005).

Prior knowledge and understanding move in a cycle (Zemelman, Daniels, & Hyde, 2005). New information is learned with every new experience. Reading, research, investigation, inquiry, note taking, and conversation all produce knowledge unique to individual students. Students use these knowledge funds as a basis for understanding new material. When moving to the next topic or course, the knowledge they have learned is part of the prior knowledge for future course. Using a student's understanding and addressing

misconceptions creates a knowledge base to learn both current content and future course material.

Teachers who utilize the information students already know teach students to constantly change and improve their ideas (Marzano, 1991). By challenging, guiding, and restructuring student knowledge, teachers help students redirect, improve, and use their findings as the basis for solving future problems and explaining observations (Kuhn, 1996; Marzano, 1991). Teachers guide students by continually challenging their ideas and providing opportunity for students to analyze their own knowledge (Kuhn, 1996). A 1984 study, by Palincsar and Brown, supported the use of cognitive activities requiring students to summarize, question, clarify, and predict outcomes to reshape ideas and increase retention and fluency of new found understandings. Further, Rivard supports the incorporation of writing in these activities to increase cognitive affect and improve concept mastery and internalization (1994).

Establishing prior knowledge creates scaffolding whereas restructuring leads to effective retention of new information. Knowledge restructuring is a more effective means of learning. Preconceived notions in subjects learned through a student's life experience can either lead to accurate understandings or to the reinforcement of misconceptions. Regardless of a teacher's attention to prior knowledge students can maintain misconceptions if not allowed to work

through those misconceptions, or they can build new theories to accommodate their previous understandings (Schneps, M., Crouse, L., Harvard University, Smithsonian Institution, & Project STAR.,2002). Information is more often correctly retained when it is based on a misconception that has been restructured. Greater learning occurs when analyzing, rethinking, and revising misconceptions are brought into alignment with scientific theory and law rather than by simply learning a theory through instruction (Marzano, 1991). Regardless of accuracy, people rarely abandon these beliefs (Schneps, et al., 2002). Rather than ask students to abandon their inaccurate certainties, Marzano recommends the approach of guiding their transformation to accurate theory. The process is called knowledge restructuring (1991).

Providing opportunities for students to focus on self-held theories promotes higher-level thinking and leads to student restructuring of knowledge without the teacher (Marzano, 1991). It is not good enough for a teacher to tell material or elicit prior knowledge. People learn by adding conceptual ideas and by changing existing thoughts and beliefs and the methods in which they are applied.

Knowledge restructuring occurs when students are given the opportunity to bring multiple sources of knowledge together, including their own, in meaningful and challenging tasks. These lessons and tasks, push the upper

limits of the zone of proximal development, termed by Vygotsky as the appropriate, most effective level of challenge for an individual (1986). New ideas are developed concurrently through content acquisition and understanding. New concepts, facts, details, and strategies are then associated with content. This organizes facts and concepts in the brain and makes information more readily available for better, more efficient recollection.

Common activities for restructuring knowledge involve the writing process. Through extended expository writing students discover theories and develop fluency of theories. The writing process develops understanding as well as internalizes and conditions material (Rivard, 1994). Incorporating Vygotsky's theories of social learning, the use of both writing and talk in co-construction of new concepts proves to be more effective in both high and low performing students (Rivard, 2004). Using collaboration to promote sharing leads to formal and informal instructional time. Talk, mediation, and argumentation promotes the construction of ideas, in groups, and writing aides the retention of knowledge and formalization of material in an individual setting.

Malachowski (1988) uses journaling to connect real life observations to science class. Malachowski teaches chemistry at the University of San Diego to non-science majors, an audience similar to that of a high school chemistry class. In both Malachowski's class and high school chemistry classes, teachers present

science to a population of students who are required to take chemistry, many without any interest in science. Enrollment is not a choice and most students have strengths in other areas. Writing, albeit a logistical approach, is more artistic and plays to the strengths of many non-science students. Students use communication skills to learn science standards through meaningful, at home, reflective, journal writing activities.

Students create a context for learned concepts and are able to call upon concepts when presented with questions utilizing the information. With written logs in response to writing prompts, Malachowski teaches his students to explain everyday observations with scientific concepts (1988). When students write to explain phenomena, they look at larger chunks of material. Through written analysis, students focus more on big ideas (Rivard, 1994). Conversely, in note taking and reading, students tend to look at smaller bits of information, dissociating small ideas from the big picture and underlying concepts (Rivard, 1994). Although the proposed implementation in this study is not specifically journaling, the effect it has on conceptual understanding is similar. Journaling, in this case, is used to connect outside observation and information to class curriculum. This is accomplished even though the meaningful observations discussed are often everyday experiences that lack conceptual challenge (Malachowski, 1988).

Metacognition

Reflection and analysis of thought are examples of metacognition that lead toward conceptual change. Kuhn (1996) and Marzano (1991) agree in restructuring knowledge by disproving currently held theories. Despite the difference in focus, Kuhn (1996) speaking of general scientific advancement of knowledge and Marzano (1991) referring to the restructuring of student knowledge in aiding students in attaining new understandings, both point to the use and metacognitive analysis of prior understanding for advancement. As students practice gaining experience with challenging others' ideas, they learn to challenge their own ideas. While challenging other ideas students learn to challenge their own, this learned practice of analyzing personal ideas and improving upon them is self-regulation, a metacognitive process. Teaching students to assess, plan, follow a plan, and evaluate decisions gives students the tools to successfully approach problems (Pugalee, 2001). As students practice metacognitive strategies with content specific material, they learn to use these strategies in other subjects. The practice of using metacognitive problem solving strategies is commonly called critical thinking. Due to the analysis and reflective steps of the scientific method and scientifically solving problems, these processes are considered metacognitive processes.

Students become more metacognitive learners as they become aware of their process applied in attaining an answer, also referred to as their inner speech. Inner speech is our internal dialogue, our inner speech. We use this inner speech to both reflect and analyze past decisions and prepare for future decisions (Wells, 2007). Students become aware of their inner speech through writing as they communicate their thought process in a way that makes sense to others. As students become aware of their inner speech, they consequently become more aware of their problem solving methodology (Langer, 1986; Pugalee, 2001).

Metacognition may be developed through the use and translation of inner speech into a written product (Langer & Applebee, 1986). Students already use inner speech, many unaware of the purpose. Although they are unable to control the inner speech of students, teachers can control the tasks students perform enabling them to better access their inner speech. Students may choose to verbalize their problem solving process, in turn demonstrating their inner dialogue. Talking through a problem naturally separates problem solving into stages. Stages of problem solving are broken into four stages: predicting, planning, revising, and checking (Pugalee, 2001). Although an order for these steps is implied, students may take different routes to solving identical problems. Verbalizing the stepwise nature of problem solving is unnatural, but it is an

effective strategy of teaching and developing metacognition in students.

Through metacognitive analysis and revision of ideas and solutions, students become aware of flaws and inadequacies in solution rationale. Revision of incomplete solutions produces a more coherent answer.

Another effective means of developing student awareness of inner speech is through the writing process. Students can write a process or explanation of the problem solving steps. Whether students use common or academic vocabulary, this process still requires thinking, rethinking, writing, and rewriting (Rivard, 2004; Langer, 1986). By translating and writing thought processes students are required to give their own unique explanation of the process. While students answer the same problem and many arrive at the same answer, students may use different, correct, methods of solving the problem.

Teaching students to use their inner speech gives them metacognitive awareness and provides students with the opportunity to become metacognitive learners. Students can learn to approach problems scientifically by becoming aware of their thinking and ideas then analyzing the validity of their thinking, and restructuring current thoughts and ideas to accurate theories. Higher order, metacognitive thinkers are more likely to see holes in their own logic and inaccuracies in their misconceptions. Allowing students to analyze their thinking promotes the growth and restructuring of knowledge (Marzano, 1991).

In the lab environment, students are more able to break down laboratory investigations to seek a better way of performing a task and construct methods for solving problems different from those previously completed. Students aware of their explanations of observable phenomena, learn to analyze the validity of explanations and challenge ideas to come to a better explanation.

Conclusion

The research presented does not support teaching through telling, the research supports student-centered instruction that promotes critical thinking. Telling is the teacher-lead presentation of new concepts and strategies to students. Student thinking requires that students explain phenomena, then analyze and rethink explanations, in order to restructure knowledge and thought processing for the sake of learning new material. For students to restructure what they know they must be motivated to learn and learn to analyze their thinking.

Engaging in this teaching model utilizes student deficiencies in knowledge. Students learn new material as the teacher guides students to recognize inadequacies in their own knowledge or thought processes. Students are engaged to obtain correct answers or explain an authentic problem or observation.

Cognitive processes in chemistry allow for material to become more fluent and retainable. By creating a mental organization system through conditional association, concepts are more readily available for students to recall in situations they find in class, on assessments, and outside the class.

Metacognitive development through chemistry instruction creates students who are more apt to alter misconceptions and derive new knowledge. Metacognitive students are open to restructuring knowledge to learn new content. This leads to success beyond the scope of the course and prepares students for success at higher levels of instruction in high school and at the university level. Teaching students to think about their own understanding and to validate or reshape thinking develops a high order thinking and transferable skills.

Chapter IV: Review of Current Curriculum

Introduction

Three levels of high school chemistry are examined in this chapter to analyze the focus of the curriculum. Chemical concepts are consistent through the three levels of curricula, the focus of each course is slightly different. General chemistry, the advanced placement (AP) chemistry, and the international baccalaureate (IB) chemistry are the title courses of the curricula examined through this chapter. Students, in each of the three levels of chemistry, take a culminating exam. The three culminating exams, California standards tests, AP tests, and IB tests, require a specific skill-set of those taking the test. Student success on these tests drives the focus of the curriculum on procedural knowledge, conceptual knowledge, or a combination of the two.

The levels of chemistry discussed follow an order in which routine, procedural tasks are performed first and conceptual, critical thinking tasks are performed later. Procedural tasks refer to calculations and fact recollection where conceptual tasks require understanding the theories behind the task. Beginning with general chemistry, the first available chemistry course in high schools, students learn the basic problem solving methods and are briefly

introduced to conceptual chemical knowledge. Students learn to apply the structures and procedures of math to chemistry problems. The focus of general chemistry is to provide students with a breadth of methods rather than a depth of understanding. The required level of thinking is limited to retention and understanding (Anderson & National Society for the Study of Education, 1994). In subsequent years of chemistry, AP and IB students focus on conceptual relationships combined with procedural calculations to develop understanding and application of concepts. In general chemistry students learn a calculation type paired with a single concept, where as in AP and IB chemistry students learn to relate multiple calculation types and chemical concepts to a single problem. These higher levels of chemistry require understanding, application, and critical thinking (Anderson & National Society for the Study of Education, 1994).

The curricular analysis that follows will center on the use of writing in the curriculum to learn, interpret, and communicate learned information. Written explanations are mandated in AP and IB science courses as an assessment tool where students learn to communicate their understanding of complex topics and point out relationships between simpler topics. In my district, teachers of general science focus on facts and tend to require less writing while AP and IB

teachers require large amounts of writing due to a focus of linking concepts and understanding big ideas.

General Chemistry

Chemistry is classified as a laboratory based physical science course fulfilling requirements for both the University of California and California State University systems. Despite the laboratory science classification, there are no requirements for laboratory investigations or time spent in labs, and there are no laboratory requirements on standardized examinations. An individual instructor controls the amount of time allocated for laboratory investigations. Labs may be added or removed from a course due to pacing concerns, levels of understanding, or departmental funds available for purchasing chemicals and lab equipment. Teachers in my school perform labs at a frequency of once a week to once a semester. Teachers in my district cut labs to speed through coverage of topics and catch-up to standardized pacing. Teachers are less accountable to course classification as they are to the standards tests taken at the end of the school year.

The state of California has refocused chemistry by outlining the essential elements of chemistry taught in public schools in California. The implementation of state science standards were soon followed by standardized,

summative assessments at the culmination of each year of science. Authors rewrote textbooks to accommodate the language of chemistry standards and publishers began to include references to standards in the chapters of the textbooks. Textbooks and teaching methods are now geared to help students pass the California Standards Test (CST).

High school general chemistry courses cover a large breadth of material without the depth of advanced classes. The course material in general chemistry builds from simple particles to complex substances through the year. Students begin each year with a study of atoms and then learn to combine atoms to make compounds. Finally students look at many compounds and the result of mixtures and reactions of compounds. Throughout the studies listed above simple concepts and calculations of energy, motion, space, and visible observations are incorporated to study atoms and compounds. Although summarized in a few sentences the amount of material is large.

Oftentimes students comment that the material in one chapter does not relate to the material in another. According to Bransford, Brown, and Cocking (2000), the lack of relationships between concepts is not the most suitable environment for increasing retention, understanding, and transfer of concepts.

Teaching disconnected facts rather than promoting understanding creates a disconnection of ideas and opposes understanding of big ideas.

The topical sequence mentioned above allows teachers to effectively teach students in a way that maximizes California Standards Test (CST) scores. To focus chemistry curriculum on fact recollection and the memorization of concepts and key terms tested on the CST, teachers in my department spend the majority of allotted class time on calculations, problem solving, and note taking. Teachers skim chemical concepts to move to calculation practice. Teachers present rigid problem solving techniques to students through notes, and then have students memorize these techniques through the repetition of practice problems until students are proficient. Through repeated lectures and drill, students are given the skills to pass the CST in chemistry.

Advanced Placement (AP) Chemistry Curriculum

The advanced placement (AP) curriculum is a college level chemistry class taught in high school. Culminating with a standardized test, the AP subject test, students have an opportunity to receive college credit for the course. All AP courses are given a grade boost by high schools and universities, increasing a student's grade point average (GPA). A student's motivation for taking and excelling in chemistry comes from the weighted GPA and possible full year of

college chemistry. From September to May, students cover the entire first year college chemistry materials, approximately the same amount of time college students receive. The course includes both laboratory investigations and college level tests. AP chemistry covers the same topics as a general chemistry course, but to a greater depth. Each section has more information and a larger variation of problem possibilities. AP chemistry is a fast paced course covering a large amount of material. At the end of the course, students take the AP test, which determines if a student will receive college credit for the course.

The AP chemistry exam is an assessment built to thoroughly test both knowledge and concept understanding. Questions assess memorization of details, application of cause and effect relationships, and concept integration. The AP test in chemistry contains multiple choice and free response sections. The multiple choice section of the test is made of 75 questions focused on procedural knowledge. This section comprises approximately one half of the overall score for the exam. The free response section has changed over the years, but contains six free response questions. The free response questions require multiple concept applications, lengthy calculations, and essay writing. The essay writing section is used to incorporate all chapters of chemistry that do not have calculations or chapters with calculations requiring interpretation.

Focus of the course shifts to and from procedural recall to conceptual understanding of AP chemistry. The breadth of material covered requires teachers to push students quickly through concepts, facts, and procedural calculations. The combination of concepts, facts, and procedures decreases the likelihood that teachers will present students with all variations of problems on the AP test. The large variation of question types in AP chemistry increases the difficulty level of AP chemistry, whereas general chemistry test questions are limited in the amount of variation of questions due to the limited content covered in the course. Students in AP chemistry require deeper conceptual understanding of material to adapt and apply learned concepts to new situations and a larger array of problems.

AP chemistry curriculum instills a strong conceptual basis required to apply appropriate concepts to new problems and to relate multiple concepts to a single problem. For example, the first question of the AP chemistry test in the free response section is always an equilibrium question. This question will, in some way ask students to apply equilibrium constants, expressions, or calculations to the problem. This, however, only makes up one third of the problem. The other parts of the problem may incorporate gas behavior, thermodynamic data, rates of reactions, or acid base chemistry. Students use the

clues from the problem to distinguish which concepts to use in subsequent problems.

Teachers adjust instructional methods so students are more capable of succeeding at these difficult problems. Teachers spend a majority of their time teaching the concepts and the conditions of problem solving. Teachers present students with new problems and new situations in class to provide them with experience applying concepts in different ways. For example, not every equilibrium problem will explicitly have the word, equilibrium, in the text of the problem. Proficient AP chemistry students understand the concept of equilibrium and look for clues in problems and then apply their procedural knowledge to solve these problems. The use of clues to determine which process to apply to a specific problem requires an internal organization of material under big ideas rather than a set of unconnected facts. In this sense, AP chemistry students are required to become experts in AP chemistry, whereas general chemistry students can be novices (Bransford, et al., 2000). The focus of curriculum in AP chemistry is to build understanding and application of concepts to answer new questions. Although teaching methods vary, AP chemistry curriculum is structured to develop both procedural and conceptual understanding and proficiency. Students learn to apply appropriate concepts at

appropriate times when presented with a new question, using conditions in the question that signify the use of specific concepts.

International Baccalaureate (IB) Chemistry Curriculum:

The IB curriculum is a research based, advanced, high school level curriculum. Of the curricula mentioned in this section, IB curriculum is the most recently developed. Like the AP chemistry course, high schools and universities give IB chemistry a grade boost; however, IB courses are seldom eligible for college credit. In contrast to the breadth of material covered in the AP curriculum, IB chemistry covers fewer topics to a much greater depth with a focus on true inquiry.

Labs in IB are true investigations with a focus on the collection of data, analysis of data, and communication of results. Lab assignments are given to students with little more than one sentence explaining the purpose of the investigation. For example, "Create a buffer where pH of the solution is five." From here, students are required to research and create buffers. Students may collaborate on the conceptual basis of the study, but the actual product is an individual decision. Reports of the lab require thoroughly written explanations of concepts, methods, data, and results of the investigation. Extensively written lab reports differentiate IB chemistry from general and AP chemistry. Like IB lab

reports, students are encouraged to collaborate through the course, but the end products are individual assessments.

IB chemistry is both a highly directed and inquiry course. While the number of topics is limited, the inquiry in the laboratory experiments creates opportunities for students to expand their application and understanding of a topic or concept. Through the writing required in the laboratory investigations, students learn to connect concepts to phenomena experienced in a laboratory setting. The connection in this inquiry portion of the course supports the goal of deeper understanding in the IB curriculum.

Although an advanced course, IB chemistry does not cover the breadth of the AP chemistry course. IB curriculum is more narrowly focused than AP chemistry. Rather than having numerous topics of coverage, IB has specific standards and objectives for students that require more depth of study than breadth. The IB standards list student objectives that require students to have a greater depth of knowledge and understanding. The specific IB standards and objectives give more direction deep into material than broad topics of AP and general chemistry.

IB curriculum has an element of choice for specific areas of study. IB chemistry reserves two sections, considered elective sections, in which students

select from a list of assessed focus. These sections give students choice over the course of the year allowing students to direct a portion of the course to focus their study based toward areas of personal interest. Student choice supports more authentic learning, leading to an increase in motivation and engagement (Deci, 1995).

Conclusion

The curricula for two levels of chemistry, ranging from beginning (general chemistry) to advanced (advanced placement and International baccalaureate) were analyzed through this chapter. General chemistry curriculum is focused on factual memorization and procedural knowledge. The current goal of general chemistry is to prepare students to achieve a passing score on a standardized summative assessment. Altering the curriculum to encompass more of the AP and IB strategies would shift the goal of the curriculum from student success on tests to student development and understanding without negatively affecting test scores.

Curriculum of this study.

The focus of this study is the implementation of writing in general chemistry curriculum to develop students' critical thinking ability. This is a strategy for adding cognitive and metacognitive development to the curriculum

while maintaining student engagement. Writing, as shown earlier, increases cognitive organization and metacognitive analysis of preconceived theories and allows for the restructuring of knowledge rather than the acquisition of facts. Modifying the curriculum, by adding a writing component that focuses on problem solving, better aligns general chemistry to research promoting cognitive and metacognitive development through conceptual understanding.

Research summary.

Research supports cognitive and metacognitive benefits of teaching through the *Think for Yourself* curriculum. The synthesis of material and revision of previous thought processes cause alterations in knowledge through the reflection of prior thinking. Learning new ideas requires that old ideas are challenged and proven false (Marzano 1991). This not only enhances the knowledge of a specific topic, but also teaches students to be metacognitive thinkers, who constantly question their current thoughts to increase the accuracy of personal theories. Synthesis of extended expository writing requires the use of big concepts rather than smaller bits of information (Rivard, 1994). Grouping the material into big ideas organizes the material and improves cognitive ability, increasing recall and application of these ideas to multiple settings (Bransford, et al., 2000). Big ideas are far less numerous than the multitude of standards and

facts students are currently required to memorize and recall. Big ideas, which are the focus of the papers, organize content in the brain to allow for fluent retrieval of information, and accurate application of concepts to appropriate problems (Bransford, et al., 2000).

Summary of need.

The implemented curriculum focuses on student development of scientific theories. Traditional methods of lecture and direct instruction have their place, but once teachers turn to write on the board or switch on the overhead or LCD projector students tend to disengage. As a teacher I not only need to cover material, I need to create opportunities for students to learn and retain information.

I tell my students that chemistry is everywhere and it can explain most things they encounter in their lives. The curriculum I have implemented is my attempt to prove this to my students. Think for Yourself curriculum is based on the notion that simple concepts explain a majority of the observations experienced in daily life. With this curriculum I ask questions about student life that, at first glance, do not seem academic or related to the classroom. By asking these questions I challenge my students to use what they know to explain what

they see and why things happen. My goal is to bring a subject as unpopular as chemistry to the center of discussions.

In explaining the processes, observations, and phenomena of everyday life students practice many transferrable skills. To explain the phenomena I present, students must apply conceptual reasoning to prior knowledge. They must consolidate their ideas about how the world works, break down life into variables and constants, and make decisions regarding what is important and what can be ignored. Reflecting on these ideas requires students to be metacognitive thinkers, poking holes in their explanations, and testing their ideas to develop theories based on preconceived notions. Students discuss the outcomes of their thinking and negotiate with other students using similar phenomena to strengthen their personal theory and develop a more widely accepted scientific theory.

The focus of the curriculum is to teach transferrable skills by learning to approach problems scientifically. The course of developing scientific theories follows the scientific method, which although tied closely to scientists, is practiced by people far from the label of a traditional scientist. Through these discussions, students learn to work with other people and their conflicting ideas. Learning to work with others to come to a collective idea that is superior to either

single idea is practice in collaborative work. In writing and discussing their thoughts, students learn to communicate both on paper as well as through constructive talk.

Curriculum focus.

The skills students learn through chemistry are the focus of the course; content presented is a tool for learning these skills. I would like students to be so engaged that they pursue endeavors in science, but those who do not, still gain an appreciation for the course, while also developing cognitive and metacognitive skills that will help them in other facets of education.

This methodology gives students an opportunity to break down big ideas. Problem solving itself becomes a conditioned concept. Searching for solutions and supporting problem solving methods is a challenging task that engages students to find solutions without relying on a procedure mandated by a teacher. Students become engaged discovering the process themselves rather than as a result of being told to do something a certain way. Students often forget how to solve a particular problem type, rather than relying on patterns in problem solving to approach all types of problems. This study will analyze the effect of the curriculum on problem solving strategies and how such a curriculum can

affect a student's ability to perform at higher levels on questions that are less about memorization, but more about application.

Chapter V: Think for Yourself Curriculum for writing in chemistry

Overview of Curriculum

Teachers focus on developing students' cognitive and metacognitive ability using the Think for Yourself (TFY) curriculum in chemistry.

Traditionally, teachers instruct and pass content to students. Following instruction, students rely on the teacher to answer questions regarding real life and the application of content to life outside the classroom. The TFY curriculum flips the process. It requires that teachers ask students about real life phenomena and then to guide students in building content from the analysis of authentic experiences and theories to explain phenomena. Teachers act as guides more than instructors while students develop, analyze, challenge, and reshape their own ideas in order to alter or validate their personal theories. This practice enables students to think for themselves.

For the sake of clarity, there needs to be a distinction between ideas, theories, and scientific theories as many people use them interchangeably. For the purpose of this study these terms are specific to stages of the problem solving process and the scientific method. Ideas are the preliminary, student generated thoughts, rationalizations, and conceptual explanations used to explain

situations and solve problems. Scientists label these ideas as the hypothesis.

From the testing of ideas and the support of concepts, students develop theories.

Theories represent the best explanation of a phenomenon with the information provided. Theories, in this study, are different from scientific theories. In the scientific method, theories refer to the explanation of experimental results that require additional testing for verification and validity. Through continued testing, analysis, and adjustment these theories will become more closely aligned with scientific theories. Scientific theories are the explanations accepted by the scientific community. These are the theories for which the standards are based and what the textbook would deem correct.

Scientific theory construction may be an individual or collaborative process. Following an individual written activity, students challenge, change, and build ideas in groups. Social learning provides students with the opportunity to share thought processes and build upon understanding through discussion and negotiated dialogue. Group and individual settings for concept development are utilized to decrease student dependency on groups.

Goal 1. Students will improve their problem-solving skills through the practice and application of reflection of problem solving methods on both conceptual and procedural problems.

Students develop problem-solving skills through the construction, analysis, restructuring, and retesting of ideas and methods. TFY focuses on the student centered construction of concepts and problem solving procedures in chemistry. As described below, students approach conceptual problems through the conceptual writing activity and procedural problems through the problem solving analysis activity. In each of the activities, students build ideas from prior knowledge through writing and discussion. Students continually test and modify ideas to construct improved theories and align these theories with scientific theory, deriving standard content for the course. Through conceptual development or the explanation and analysis of problem solving strategies, a student's ideas are challenged to improve methods until students have developed a correct theory or proficiency in solving problems associated with the concept.

Goal 2: Students will be engaged in their learning.

I will provide students with challenging problems that relate directly to their lives. Conceptual reasoning problems present scenarios or phenomena

students have observed or recall. Students apply prior knowledge and experience to create viable explanations for presented scenarios. The scenarios and phenomena used directly apply to students. Authenticity presents content in the context of student lives and the challenge of explanation of student life present opportunities for success.

Goal 3: Students will improve in their ongoing development of scientific literacy as evidenced by their ability to effectively approach problems scientifically.

Through the rationalization of everyday phenomena, students develop the ability and fluency to apply concepts learned in chemistry to daily observations. Reflecting and challenging rationale creates rationale more aligned with actual explanations. This ability to apply science to life in order to solve new problems is scientific literacy. Applying scientific reasoning and concepts to decisions leads to a more well-informed decision.

Implementation Overview

What is the effect of TFY on students in a collaborative classroom? The TFY approach pairs two forms of writing, conceptual and analytical, to develop both conceptual and procedural problem solving skills. Conceptual writing and problem solving analysis are the primary activities in this series. Conceptual

writing takes the form of written explanations completed in class, and concept application as homework. Analytical writing is student writing to examine problem solving practices.

Conceptual writing activity.

Concept Writing is an activity occurring throughout the week, prior to any discussion or lecture of a concept or topic. In these conceptual writing activities, students use their prior knowledge to explain an assigned or presented phenomenon, hopefully one that has been witnessed in everyday life. Students perform the conceptual writing activity to conceptually rationalize presented observations using prior knowledge and creativity thus developing personal ideas and movement toward scientific theory. This process resembles the scientific method of hypothesis, testing ideas, and developing theories, though students are unaware of the scientific nature of the activity and have not researched content or read relevant literature, they form hypotheses by using prior knowledge and experience. As a guide, the role of the teacher is to influence conceptual change by challenging incorrect explanations (Kuhn, 1996).

There are several ways the conceptual writing element is added to the curriculum. Conceptual writing is performed in class as a class commencement activity. As an opening activity the projector comes on and projects a prompt.

Students discuss the question, video, picture, or statement and move to write a one-paragraph response to the prompt. With the time constraints of class, it is feasible to give one question or prompt. As homework, the conceptual writing is presented as a set of two to six questions, each requiring a one-paragraph explanation. The purpose of the homework assignment is to further challenge student theories and incorporate the academic vocabulary and concepts presented in class.

Concept discussions.

I pair concept discussions with concept writing activities. Students first construct, through the conceptual writing activity, individual theories based on provided prompts. Then students collaborate to challenge ideas, build theories, and draw connections to the observations presented. The discussion provides a forum for collaboration on individual work. These discussions build on the foundation of individual writings done either a few minutes before or the night prior. Each discussion has a specific goal. Students are presented with an analysis question. "Identify understandings or misunderstandings." "What are the common themes in what each group member wrote?"

Problem solving analysis.

I assign calculation-based homework problems in chemistry. Students show work and answer the questions as reinforcement of the learned process. The problem solving analysis is an analysis of the steps taken to solve a calculation problem that I have added to the homework problem set. While answering the questions given, students complete the analysis of one problem. Students are then required to think through the problem and write to explain the steps performed, assess the effectiveness of the procedure, self-regulate their progress, and predict the accuracy of their answer.

Secondary activities.

The secondary, supplemental, activities include class discussions and weekly formative assessments. Class discussion is the method of analyzing writings in small groups, and class wide sharing of collective group understandings and misunderstandings. Weekly formative assessments are online quizzes containing 15 questions designed to check for understanding of the concepts and skills for the week.

In the curriculum discussed, I have left out the activities traditionally done throughout chemistry classes such as labs. Chemistry is a lab-based course; however, I have left out labs of the curriculum. This is not to imply that labs are

less important or not used in my classroom. Labs are implemented and completed weekly. However, lab work is ubiquitous to the chemistry curriculum and therefore, having not changed the presentation or implementation of labs in my classroom, labs are not mentioned.

Conclusions

The TFY curriculum is an addition to the current curricula used in chemistry. Teachers may use the activities of the curriculum daily. By opening a class with a conceptual writing question and adding problem-solving analysis to calculation-based problems teachers shift course focus with limited planning and time investment.

It is important to note that, due to the weekly school schedules, classes meet three times per week. I have structured class activities to meet these constraints. Monday is a traditional 52-minute class focused on conceptual learning. Conceptual writing takes place at the beginning of the period and the lesson extends from the results of the writing and ensuing discussion. The final two weekly meetings, Wednesday and Friday, are both 100-minute, block, class periods. Wednesday is a quantitatively focused day. Students learn to solve calculation-based problems. Friday wraps up the week by relating the concepts

constructed on Monday with the calculations learned on Wednesday. This generic plan repeats weekly with the activities described.

Chapter VI: Implementation

School Setting

The implementation of the *Think for Yourself (TFY)* model took place in southern Orange County, California at Orange County High School (OCHS). OCHS is a predominantly affluent community with a 20% English language (EL) learner population. Although the district, as a whole, maintains schools with Academic Performance Indexes (API) above 800, there is a large achievement gap between native English speaking students and EL students. Of all the high schools, OCHS has the largest EL student population in the district. As a program improvement district, the focus of the district has shifted from raising the API to closing the gap between English language learners and native speaking students.

The college preparation track for science at OCHS follows the progression of biology in either the ninth or tenth grade, followed by chemistry. At OCHS chemistry is the main physical lab science students take to fulfill the University of California entrance requirement with a small percentage of students opting to take physics instead of chemistry. Following this two year progression, students have the choice to continue in science with advanced placement and

international baccalaureate biology, chemistry, or physics as well as courses in environmental science, marine ecology, and anatomy.

Class Setting

My class structure and curriculum are geared toward students who have not experienced success in their previous science or math classes. During my five years at OCHS, I have developed a reputation as being an outgoing chemistry teacher. Students who are normally not “science students” do well in my class and the guidance department, who controls the scheduling of students, places students in my class who have struggled in their previous biology courses. As a mainstreaming school, high functioning special education students and EL students are mixed with regular classes. For this reason, the type of students I teach are not students intrinsically motivated to participate in high school science because they have not experienced much success in other science classes.

Students in my first period class are the focus of the study. The schedules of classes are a mixture of traditional and block scheduling. Monday, our traditional school day, consists of six, 52 minute classes. The block schedule days consist of three periods of 100 minutes each and make up the remainder of the week. Between the first two periods of the day is a tutorial period, students attend one of their classes and receive tutoring from their teacher or another

student. Between the second and third period of the day, students eat lunch.

The block school days switch between even periods (periods 2, 4, 6) meeting on Tuesday and Thursday and odd periods (periods 1, 3, 5) meeting Wednesday and Friday. My first period class, the focus of the study, meets on Mondays from eight to nine, and Wednesdays and Fridays from eight to ten, approximately.

There are 36 students in the class consisting of regular education, high functioning special education, and EL classified students.

Teacher

Different personalities are drawn toward the use of different teaching styles. Throughout my student teaching I was encouraged to identify a teaching style that would best suit my personality. During my first seven years of teaching I have found that my teaching style fits my personality. I am an outgoing chemistry teacher who likes to ask challenging questions and work with students. Students say they enjoy my class because we talk about “cool things.” In reality, they often ask me questions and we work together to figure out the answers. Students are amazed with the number of questions that can be answered with a foundation of simple principles.

Preparation

The TFY curriculum is a curriculum with minimal preparation time required for implementation. Teachers are able to test the effectiveness of this curriculum with a rather small investment of time. The activities require little preparation as most of the work falls on the student. The difficult part of preparation comes from the development of conceptual writing prompts. I was challenged in creating conceptual writing prompts, questions, observations, and phenomena. These prompts must rely solely upon prior content knowledge and while remaining complex enough for students to communicate their personal theories. Constructed prompts must fall in the zone of proximal development (ZPD) of every student (Vygotsky, 1986). If the level of the prompt is too high then it is assumed students have prior content knowledge; if the level is too low, then students' misconceptions and personal theories are not challenged. Most of the preparation time was spent on the development of these questions. The questions presented through this curriculum may, or may not, be suitable for the level of students in another classroom. The questions presented may be used in another classroom, altered to fit the ZPD of the students, or replaced to suit the context and expertise of the teacher.

Pre-Implementation

Through the course of the pre-implementation, a majority of my time was spent modeling the activities and making sure expectations for the writing activities were clear. To make sure students produced written responses of sufficient quality, I walked through these activities with students. In each case, I went through the activity just as I would in the implementation. After performing the activity, the class and I walked through the writing model collaboratively. This gave students an opportunity to realign their thoughts and writing to match the format I expected.

The conceptual writing responses required re-teaching the structure of written paragraphs. Although similar to a free-write, I required a specific structure of the conceptual writing responses. Conceptual writing activities require students write from their personal experience, using individual reasoning skills without prerequisite content knowledge. Student paragraph structure reduced the effectiveness of the communication of ideas. To improve written responses I decided to hold students accountable to correct paragraph form. I noticed most students led with evidence, and then proposed a conclusion as the final sentence of a paragraph. I taught students to adjust their writing by formulating an opening sentence that states the conclusion, main idea, or claim

followed by supporting sentences as opposed to the current format of evidence first followed by a conclusion. These writings, much like an argument for student ideas, should lead with a claim, followed by the supporting evidence. Not only does this make the claim more visible, but creates a more clear argument as students are aware of the argument students are presenting before reading evidence.

To model correct format, I wrote the evidence and rationale for questions on the board. I then rearranged evidence and the main idea to construct a more understandable paragraph. Paragraph structure became a focus of the students' generated responses to the writing prompts. Many other revisions could have been made including word choice and sentence structure, but, due to time constraints, these were not covered for the project implementation. I taught students to put their conclusion as their topic sentence followed by evidence that supports the claim they made in the topic sentence. The most common mistake students made was the use of rising action in academic writing. By rising action, I am referring to student's use of a conclusion at the end of a paragraph and the utilization of evidence. Students put the evidence before the main point, a practice common in joke telling and story writing. I expected this as conceptual writing is naturally a generative process. Students wrote their evidence, and

then analyzed evidence to generate their ideas and personal theories. To accommodate the generative nature of writing and correct paragraph structure, I encouraged students to outline their evidence first, and leave space at the top for their conclusion. After outlining the evidence and rationale I encouraged students to fill in the main point in the open space at the top of the paragraph.

Personally, I like direction. I tend to write better when I have a clear understanding of the beginning and ending points. I made conceptual writing prompts and questions open ended to illicit abstract thinking from students, however, many students found the questions too vague. In order to focus their writing, but still give minimal direction, I used keywords with writing assignments. The use of keywords helped with the context and helped to focus responses. Keywords are academic words students should use in their explanation. I placed these words at the beginning of an assignment, not as an addition to an individual problem so students learn to assimilate words with certain problems. Students wrote from their personal experiences, but used keywords to make connections between student ideas and text. Students argued and discussed their written responses in small groups and class-wide discussions to validate or adjust their responses and ideas.

Writing for problem solving analysis (PSA) required modeling as well. The PSA is an analysis of a homework problem. The first time the class performed the problem solving analysis activity I had students complete a homework assignment at home and write the analysis in class. I assigned students a specific problem, for which they were to answer the questions “What I did?”, “Why I did it?”, “What am I sure about?”, “What am I unsure about?”, “Did I get the correct answer?”, and “How do I know?” After the first trial of this format I decided to eliminate two questions. The final format asked students “What I did?”, “Why I did it?”, “Did I get the correct answer?”, and “How do I know?” This left out the questions “What am I sure about?”, “What am I unsure about?” which proved more confusing to students than useful. Having removed these questions from the assignment, they expressed an increased level of understanding of the expectations for the PSA.

Implementation

The implementation of the *Think for Yourself* (TFY) model spanned two months and three chapters of high school chemistry. I implemented the model in the chemistry chapters of gas laws, thermochemistry, and properties of solutions (Bowers, 2007). Despite the curricular structure, there is a great deal of variability within the activities used throughout the study.

The TFY curriculum is a set of activities that fit a weekly structure. The weekly structure repeated four times during the implementation. I changed the activities weekly, depending on need, but the structure and goals of the activities remained the same. Students completed each of the activities four times through the course of the study. Each of these four is described in detail below.

Concept writing.

Students completed a free-write at the beginning of class on Mondays through the implementation. The following account is from the first use of the conceptual writing from the first day of the implementation.

I gave students two questions to answer and elaborate upon. "Why does ice cool down a drink? Why does a chemical ice pack make your arm feel cold?" I asked students to explain the phenomena using the keywords "energy transfer" or "heat transfer." I gave the class approximately 10 minutes to answer the questions requiring two to three sentence responses for each question. During this time I encouraged students to discuss topics with their groups; most began writing.

As noted earlier, student writing focused on evidence, generating the conclusion as students thought through the evidence presented. In walking around the class, I noticed students wrote evidence and reasons quickly. When

the evidence was written students discussed the meaning of the evidence with the other members of the group, trying to rationalize the bottom-line answer or conclusion. Although students wrote first, conversation started when students ran out of reasons and began to focus on the conclusion. The conclusion seemed to foster discussion in the groups.

After ten minutes, the class conversations began to grow on unrelated topics. I quieted the class and began to generate discussion from the class, recording the conversations on a printed class layout called a discussion web. The class discussion web is a tool for tracking conversations for participation. To plot the conversation I put a dot where the first response occurred. I then drew a line from table to table as the conversation continued. I reaffirmed responses to encourage continued participation by more students. In naturally occurring discussion breaks I highlighted the key points mentioned in the explanation.

In response to ice in drinks and cold packs on an arm, many student responses, although incorrect, eluded to correct concepts. Student responses mostly focused on cooling, and cold, rather than heat. Many students did not use the requested academic vocabulary. Students left out the keywords of energy transfer or heat transfer in their responses. Despite leaving out these specific phrases, students eluded to the heat transfer concept. Students used the

phrases “the cold of the ice dropped the temperature of the water,” and “fast moving liquid particles run into the slow moving ice particles.” Students used concepts of cold, which is actually the absence of heat, and molecular collisions, which is a correct theory of molecular interactions in heat transfers. Students implied heat transfer yet few mentioned the actual term heat.

To direct the conversation further I told students there is no such thing as “cold or coldness.” I explained that “cold is similar to dark, it is not an entity, it is the absence of another entity. Dark is the absence of light, cold is the absence of heat.” I asked them to try to respond without using the word cold in their explanation. With the removal of the word “cold,” students began to produce responses more in line with energy transfer theory. Without lecture notes, learning activities, or explicit teaching students began to mention concepts either by name or through implication. Students began asking “what do you call that?” when referring to the explanation they wrote. Students used heat transfer, heat absorption, heat releasing, the law of conservation of energy, and particle motion to explain the change in temperature observed in the processes assigned.

Students knew the free-writing topics well enough to forget they were science topics. Although I provided guidance to students, by challenging responses with further questions, the responses produced were completely

student generated. This activity introduced and provided a context for the chapter and the conceptual notes to follow.

Following the free-write and discussion, the students seemed more engaged than normal in the notes on the introductory concepts of the chapter. Students showed excitement as the book verified the answers they had written prior to formal learning and vocabulary terms related to individual student explanations. Beyond the discussed explanations, students continually referenced concepts they had been taught in previous science classes. Some asked if we had ever covered the material before. Several students offered “aha” moments by expressing how the concept could be applied to an observation that had bugged them for some time. Students provided examples of the topics covered: exothermic, endothermic, phase changes, and particles motion. The ten minute lecture was lengthened to a 30 minute discussion by continued student generated questions, responses, and applications.

The conceptual writing activity remains in this original form after implementation as students enjoyed the process and have expressed the phenomena as “cool.” Through the implementation, I presented students with observations, questions, videos, pictures, and presented questions about labs and demonstrations performed in class. For example, I showed a PowerPoint

presentation with before and after pictures of a train tanker implosion, presented below.

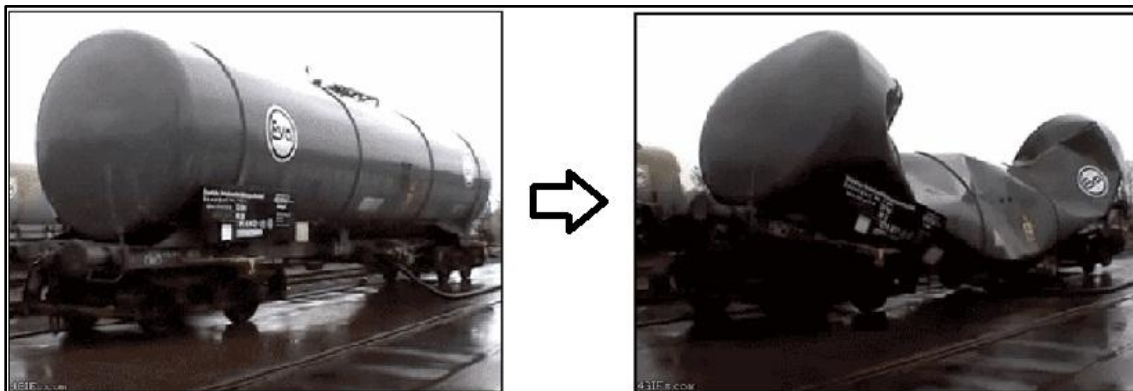


Figure 2. Imploded train tanker conceptual writing prompt presented to students.

In the third week of implementation, I presented students with the train tanker problem. The first picture is a normal, train-towed, gas tanker. The second picture shows the same tanker, only crushed. I assured students that nothing had touched the tanker and I wanted them to explain how they thought this could have happened. In addition, I showed students a video of the tanker imploding. I gave students five minutes to discuss with their table of four to five students and then individually write a one-paragraph explanation of the event. This was the start of our gas laws chapter. This was not an observation students had made prior to class nor had I given a formal lecture. The only leading information provided were the keywords: pressure, volume, temperature,

directly proportional, and inversely proportional. I asked students to incorporate keywords into their explanation.

Students began discussing and writing. Several students asked me questions about the plausibility of their explanation while others asked for more details about the timeline and location of the crushing. I denied answering each question, but instead instructed students to explain the situation with the information they knew. In their groups, students discussed the keywords. They argued and clarified the meaning of pressure, volume, and temperature and how they could affect a large, steel tanker. Students were so engaged in discussion and argumentation that I had to remind them there was a writing component. I reasserted they would be handing this in and therefore a physical product was required.

After five minutes, I asked students to read what they had written quietly to themselves. Regardless of whether or not they finished, I wanted students to reread their paragraph. After they finished reading, I asked them to circle the one sentence they felt constituted their conclusion. Many students did not have one while many students found it at the end of the paragraph. Those who did not have the sentence needed to write the sentence first. I asked them to rewrite

their paragraph with their circled or newly constructed sentence as the first sentence, their topic sentence.

Directly after the rewriting process students engaged in a think-pair-share activity. Students passed their paragraphs around their table and read the explanations of others in their group silently at their table. After reading each of the explanations, groups had one minute to come up with a one-sentence conclusion for the table. Students shared the one-sentence statements with the class. I recorded the information presented on the board and used it to transition into the lecture that followed. Toward the end of the sharing time, groups shared “we said the same thing as them.” I explained to these groups that I still wanted them to read their sentence. I told them that explanations, although pointing to the same conclusions, may use different words or phrases that help another student in the class understand. I made sure every group shared and students told me particular explanations made sense to them, even though five groups ultimately drew the same conclusion.

I used the concept writing activity throughout the course of the implementation. The preceding example shows the entire process used in the concept writing activity. I applied this same activity to multiple concepts in similar contexts. Students explained situations or observations using theories I

had not explicitly taught. For example, in thermochemistry, I asked students “why does ice cool down a drink?” and “why does a chemical ice pack feel cold?” Keywords for these writings were heat, energy, temperature, gain, and loss. In another instance, I asked students, “In the movies, when an explosion happens inside a house or a car the windows blow out. Using one of the gas laws, explain why the windows blow out.”

Explanation homework.

Mondays are solely qualitative days; there are no calculations, and the focus is learning a concept. Separating days by focus reinforces both facets of chemistry, conceptual and calculation-based (Brown and Ryoo, 2008). This modified curriculum accommodates the large qualitative, conceptual, and quantitative, numerical, components of chemistry. Calculations quantify the chemistry concepts and students struggle with both concepts and calculations in the course. To allocate time specifically focused on each, I split the conceptual and calculation aspects into different days at the beginning of the week and relate both on the final day of the week.

Explanation homework, an extension of the conceptual writing activity, is the Monday homework each week. The homework is assigned at the end of class on Monday and due the next class session, Wednesday. At the end of class on

Monday, I project the homework on the board. For the last five minutes of class I read the instructions, key terms, and questions in the homework. Students may either take a copy of the homework or access it online through the course website.

Through the course of the implementation I required students to write conceptually at home. Writing at home promotes more individual writing and provides reinforcement and extension of concepts learned in class. In the explanation homework, not only did students apply the concepts from Monday to additional situations, but homework based, conceptual discussions started the class on Wednesday.

GAS LAWS HOMEWORK

Homework

- Explain 2 situations and four graphs with the gas laws learned today.
- Key Terms – Include these in your explanations.
 - Pressure, Temperature, Volume, moles
 - Variables, Constants
 - Directly Proportional
 - Inversely proportional

For each of the following graphs

- Explain what each is showing/exemplifying.
- Tell the variables and the constants.
- Tell how the variables are related.
- Give real life examples where this law is applicable.
- Responses should be around 1 paragraph.

Relating Variables

- In the Northern plain states, car owners have to add air to their tires in the winter. Explain this practice using the gas laws. Specify variables and back up your answers.

Figure 3. Key terms in explanation homework assigned after the first day of gas laws instruction.

Figure 3 is part of the first week explanation homework. In this assignment, I presented students with four graphs and two questions to explain. The use of key terms is seen in the slide labeled 'Homework.' This slide comes before any of the writing prompts. The key terms for this assignment were pressure, temperature, volume, moles, variables, constants, directly proportional, and inversely proportional. In each explanation they may use all of the words or

only a few of them. Also shown in Figure 3 are general instructions for the homework and the first question of the homework.

I asked students to explain why air needed to be added to car tires in the northern pain states, a practice not familiar to most California students. Students were also asked to explain why movie explosions, in cars and buildings, blow out the windows. I assumed most students have seen a movie where an explosion has occurred. I constructed this homework assignment to test application of new material to new situations. As shown in the instructions in Figure 3, I required students to explain the observations listed and give the variables that caused the changes.

The graph analysis required students to use both math and chemistry knowledge to determine the relationship between the variables. Directly and inversely proportional are terms taught (?) in math. They are used to show the shape of graphs. In chemistry, the terms are used to explain a change which is dependent on the change in another variable. For example, an increase in temperature causes an increase in volume, as in a hot air balloon, the two are directly proportional.

Explanation homework assignments have a dual purpose. I wanted to present questions which require students to think critically and scientifically by

applying personal ideas and concepts to their explanations, and I wanted students to use and apply the concepts learned that week. Although students usually came back to class with questions and uncertainty (?), they began talking about the questions even before I could tell them to do so. These questions and confusions led to Wednesday conceptual discussions as the start of class.

Concept discussions.

Conceptual discussions are the collaborative elements paired with the conceptual writing and explanation homework activities. Students write, responding to a prompt given either through a homework assignment or an opening activity in class. Having completed the previously described conceptual writing or explanation homework, students engage in a discussion on the given topic. These discussions fostered both supportive statements and arguments. Arguments, in this case, contrary to the negative connotation, refer to constructive debate or presentation of conflicting ideas. In scientific discussions this type of argument is welcomed.

For the train tanker example, shown above, students immediately began discussing what they thought happened. Most concluded I had left out a detail. I stopped the conversations and projected the video of the actual crushing of the tanker. Students were amazed by the video, having seen that nothing touched

the train tanker. Once again I asked them to discuss their personal ideas and come to a table theory for the cause of the tanker crushing.

In another instance I had students pass their written responses around the table, a practice I refer to as the “pass-and-read.” Students sat in tables of four to five students and passed their papers to the left, reading the responses of each person sitting at the table. As students finished reading one paper, they passed the paper to the left, and read the next paper passed to them. When their paper returned to them, they were done. Following the pass-and-read students began the discussion.

I used the pass-and-read method to start discussions on the following questions: Why do people in the northern plane states add air to car tires in the winter? Why do the windows of a car or a building blow out when an explosion occurs in a movie? Despite being told that others would read their work, there was an initial grumble about having others read other papers, after which students read quietly. After all groups finished reading I gave them a discussion prompt. I assumed that having read the other papers they did not need to discuss the ideas each person had. Instead I asked groups to make a list of the variables and constants in each situation and whether the variables increased or

decreased. Groups quickly discussed and wrote their answer to the prompt.

Several groups had a difficult time defining constants and variables.

A student expressed that “everything changes, there isn’t a constant.” He then proved, through an explanation of the windows blowing out, that indeed pressure, volume, and temperature changed. I told him that everything will always change; the key is to limit the reference frame or time frame to simplify the explanation. I asked him, “Are you trying to explain what caused the windows to blow out or what changed as the windows blew out?” The student then explained both situations complete with variables and constants. “When an explosion happens it gets hot and the pressure increases because the gas can’t expand. The windows have to blow out to allow the gas to expand and spread out.” After hearing this I asked the group to split up the explanation at the moment when the windows actually break and insert the words pressure, volume, and temperature.

When I joined another conversation I asked why they could not come to a consensus. The groups said they could not decide which person was correct in their explanation. Several members of the indecisive groups had different explanations of the same phenomena and the groups could not eliminate any of the explanations based on their understanding of the topic. I told them to split

the group and make two lists, keep all of the explanations but pick the explanation less accepted by the class to talk about with the entire class.

Having finished the group discussions I called the groups together and gathered information for a class-wide discussion. I asked each group to select a person to speak for the group. Going around the room I solicited each group for their list of variables and constants. Having written the list of variables and constants, I asked what law they were using to explain the phenomenon. This continued around to all groups in the room. From the eight groups in the room, the class made three possible explanations of phenomenon.

After all groups responded I asked students which one was correct? Several students said that it was possible to explain with any of the explanations. They arrived at three plausible explanations for windows blowing out in an explosion. First, windows, in an explosion, blow out because pressure increases and the windows blow out to change the volume. Second, windows, in an explosion, blow out because the temperature changes and the volume changes by blowing out the windows. Third, windows blow out because the explosion changes the temperature and the pressure changes as well, causing the windows to blow out. Students were correct in their explanation of the variables but failed to rationalize their constants.

I asked students what they could reasonably say was constant in an explosion. Students agreed that temperature had to change in the explosion and could not be considered a constant. This eliminated the first explanation of pressure and volume changing. The discussion of whether pressure or volume was constant was more controversial. When the argument came to a halt I asked students about cause and effect and the frame of reference.

What do you consider to be the starting point and the ending point of the explosion? In that time frame consider just the beginning and ending pressure and volume; which one changes? After asking these questions students began to describe their rationale in context and time frame. Although students found that either could be the correct answer they decided that one was a more-correct answer. They had to decide between ending points of windows just starting to break and after the windows broke. They decided that the starting point was as the explosion just started and the ending point was after the windows blew out. Having defined this, they stated that temperature and volume were changing and the pressure was a constant.

Student discussions were more focused when given a definite goal for the discussion. In the situation given above, I gave students the discussion task of determining the variables and constants involved in their explanation. Rather

than just come to a single explanation, groups were instructed to break the problem into smaller pieces and determine the plausibility of constants and variables. I explained that, by accepting or dismissing these variables and constants, the explanation could be deemed adequate or inadequate. Through this, I showed students how breaking down a problem into smaller pieces can make the problem more manageable.

Theoretically, it is more cognitively demanding to have students develop their own questions and come to their own conclusions by leaving the discussions completely open. I did not have success with this type of inductive inquiry with adolescent students in my pre-implementation. I have found it more efficient to give a short directive for the conversation. This has allowed conversations to remain on track without much teacher intervention. If I interrupt a conversation it is to summarize a point made by students and ask a question.

Giving students a goal puts pressure on students to come up with something intelligible to present to the class after the discussion. The discussion prompt is a good conversation starter. Groups attempting to answer the question quickly in order to move on find themselves debating for the conclusion

they feel is correct. To add further accountability to the conversation I have groups fill out discussion webs.

Table # ____ Date __/__/2011														
Topic _____														
Arg			Sup		Arg			Sup						
Que	Pro		Clar		Que	Pro		Clar						
Und			Ac La		Und			Ac La						
Mis			Con Δ		Mis			Con Δ						
Name					Name									
Name					Name									
Arg			Sup		Arg			Sup						
Que	Pro		Clar		Que	Pro		Clar						
Und			Ac La		Und			Ac La						
Mis			Con Δ		Mis			Con Δ						

Figure 4. Blank discussion web for a single table.

As shown in Figure 4, a discussion web is a representation (?) of the table where conversation occurs. Students fill in their names where they are sitting. The discussion web contains checkboxes to mark statements as arguments, support, questions that ask for clarification or deeper meaning, understanding and misunderstanding, the use of academic language, and conceptual change.

Discussion webs provide students with a record of the conversation. One of the group members is the recorder, the person in charge of the discussion web. The recorder trails the conversation with lines going from person to person as the conversation progresses. The conversation starts with a dot next to the name of the person who started the conversation. A line is then drawn to the name of the person who responds and to each subsequent person participating in the conversation. Involved conversations and arguments tend to look more like a web. Beyond tracking the path of the conversation, the recorder checks the type of participation each student adds to the conversation. Upon completion of the conversation, students flip over the discussion web and make notes of the conversation they had. This not only helps to refresh the group and reflect on thinking, but it also catches up the recorder in case they were too busy recording conversations.

During the third week of the implementation, students participated in a concept discussion with discussion webs. At the beginning of class students brought their explanation homework to class. The class started with students passing their papers around their table. I told students to read the last question of the homework given at the end of the previous class. How can evaporation be

neither exothermic nor endothermic? Students passed the papers around the table.

Students read their group members' rationale on evaporation as neither exothermic (energy releasing) or endothermic (energy absorbing). Upon completion of the reading students looked at each other, not having really understood the question or how to answer it and realized that nobody else at their table did either. I told them I could rephrase the same question in a way that had seemed more applicable to them. I asked students to relate evaporation to the commonly known phenomenon that sweat cools our bodies when it gets hot. Students discussed the topic while one student from each group mapped the discussion on a discussion web.

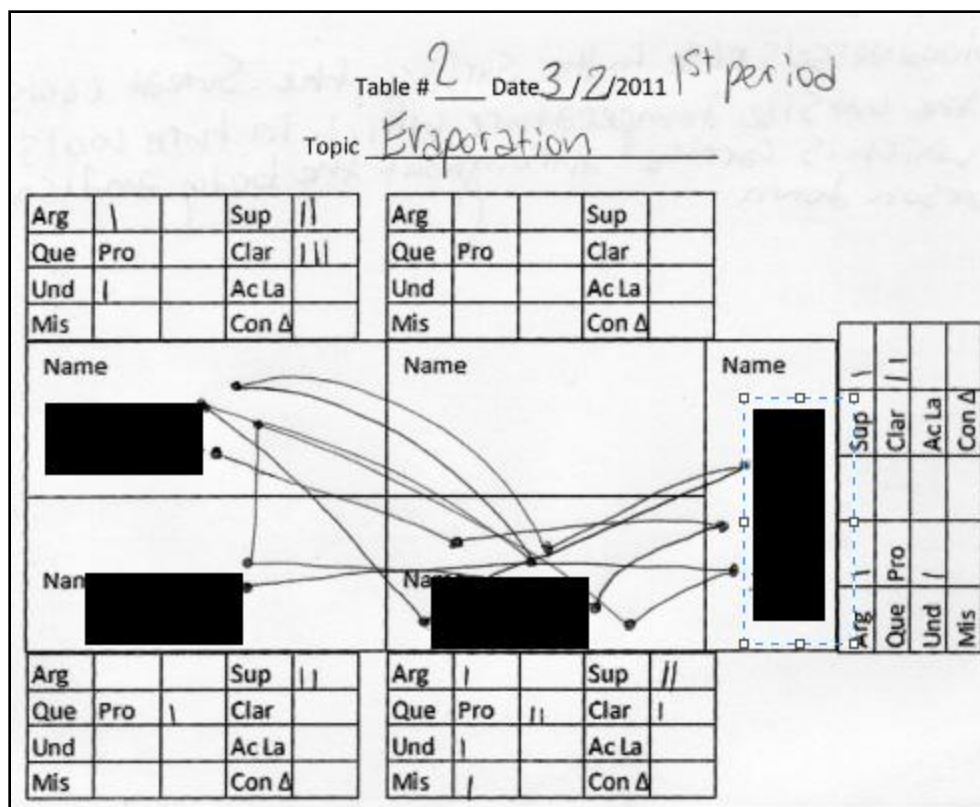


Figure 5. Discussion web on the topic of sweat completed March 2, 2011.

The discussion web shown in Figure 5 shows a group discussion on evaporation and sweating. In the conversation, the four students at the table mapped the discussion. In the discussion, all students shared, evident by the line that traces the discussion; the line shows each of the members at the table participated several times. The student in the bottom left seat at the table was the recorder of the conversation and therefore only spoke twice, the rest of the time she coded the responses of the other students.

After the five-minute conversations, I had students flip the paper over to write a one-sentence summary of what they discussed. After the minute, I started by calling on groups. One student from each group read the one-sentence blurb for the class. At times, I asked groups to clarify what they meant or to elaborate on the point they made. It is important to note that I always pointed out positive parts of the explanation to encourage students to share. Toward the end of the sharing groups announced they wrote the same thing another group said. I asked the group to share what they had written as the difference in wording might point to something another group missed. I reminded students that they often hear the same thing several times before they get it. The practice of repeatedly sharing the same conclusion drew new information from student response that was critical to understanding an observation, in this case evaporation and phase changes in general.

Calculation-based homework.

Calculation-based homework is a generic assignment given to most chemistry students. I assigned problems, requiring problem solving and calculations, from either the textbook or a worksheet. Students solved the problems with the methods gone over in class prior to the assignment. As this is a near ubiquitous practice in chemistry classes I will leave out detail of the

assignments given. The importance of this activity comes from adding the problem solving analysis. I paired the calculation-based homework with the problem solving analysis. Students chose one of the problems solved in each assignment to analyze.

Problem solving analysis.

I assigned each homework problem set with an explanation called the problem solving analysis (PSA). Students chose one problem to analyze, completed the analysis as they did their homework, and turned in the analysis with the homework. Unlike the concept writing activity, students either wrote in paragraph style, as a bulleted list, in tables, or any other method that struck them as effective as long as it was legible.

The problem solving analysis is a task requiring the students to break down the problem solving process in the context of a homework problem. I gave students an example of the analysis (see appendix page 155). In the assignment I asked students to write out the problem solving method, step-by-step, by responding to the phrase “What I Did.” Alongside the “What I Did”, section is the “Why I Did It”, section of the analysis where students give reasons why they chose to solve the problem the way they did. Finally, without knowing the actual answer, I asked students to assess their overall success in solving the

problem by answering the questions, “Did I get it correct?” and “How do I know?”

Several students misunderstood the question “Why I did it.” Students wrote, in words, the mathematical step performed in the specific problem. By writing the PSA as a class, on the board, I showed how I wanted the steps to be separated and the rationale to be written out like a proof in geometry. In geometry, at OCHS, students write proofs in a two column form. In one column they give the actual mathematical step and in the other column they give the name of the theorem or rationale for the step. I wanted students to write each step separately so they, and I, could see clearly whether each step was performed correctly. In the “Why I did that” section, over half of the students used words like multiply and divide. These words show the process, but not the reasoning behind why they did them. It is unclear whether the students were unable to show reasoning or if they just did not. The lack of reasoning lead me to model reasoning through a class-wide writing I showed students to write what was actually going on in their heads, step-by-step. Several students noted that in doing this, they actually wrote less. The prospect of writing less excited students and was a motivating point for completion of the assignment.

Students were unclear about how to tell if they were sure about their answer. Explaining how students knew whether or not they had reached the correct answer needed to be explained. I told students I wanted them to be honest about their efforts in this section. Did they know they had the right answer because they got it from a more capable peer? Did they copy the answer out of the back of the book? Did they not really understand a step and therefore feel uneasy about the way they solved the problem? I wanted to read the responses to these questions in their rationale. Being candid in this section made students uneasy, even though I reassured students they would not be penalized for what they said. If they did not like how they got the correct answer, then I told them “maybe that is not the way you should do your homework.” This section created a self-regulating accountability for students. Students expressed that they did not want to mention if they had copied it. I assured them that “using your own brain to get the wrong answer was better than using another person’s paper to get the right answer. We learn more from doing things wrong than by not doing them at all.” Students who copied received no credit for the assignment.

A majority of the students did the PSA as an afterthought to the homework. Students finished the homework problems, then, before class,

hurried to understand what they did the night before and attempted to write a coherent analysis of the process they followed to solve the problem. An example of this, was one of my students, who came to class early on Friday, February 11. He forgot to complete the problem solving analysis and began to read his work to write his PSA. As he worked through the problem analysis, he stopped and dropped his head onto the desk. He told me he had done them all wrong. When I asked him how he knew, he gave an adequate explanation of how he was supposed to solve the problems and how that was different from what he did. "I plugged the numbers into the wrong spot," he said while pointing to an equation. Harry reworked the problems with the correct method. He found his own mistakes just by writing out, in words, what he did and why he did it.

Homework quiz.

At the culmination of the week, I give students a quiz to take online. The online quizzes are due the first day of class the following week, normally a Monday unless there is a holiday weekend. Students access the internet and respond to fifteen multiple-choice questions. These quizzes are chapter cumulative, meaning there are questions covering both concepts and calculations learned during the study of the current chapter.

I grade the quizzes for accuracy, but only three grades are possible.

Quizzes are worth the same amount as a homework assignment in my class (15 points). In order to receive credit for the quiz, students need to score an 80%, or 12 out of 15, on the quiz. If they get this score by the next class meeting, Monday, they receive full credit. If they fail to do this, they may take the quiz until they receive the 80% passing grade. The maximum number of points students can earn for this is a set value of 12 points. If students do not get a score of 12 or better, with an unlimited number of trials, they get a zero.

Homework quizzes are the formative assessment tool used to judge the overall progress of students. Although these quizzes are online, I accommodated students without internet by printing copies of the quizzes and making them available for students to take. Students either submitted quizzes online or filled out the quiz at home and then entered their responses into the computer in my classroom.

Students have found they can collaborate on the quizzes. Students take the quizzes at home and a teacher does not supervise them. I encouraged students to use their notes, their books, and even the internet to look-up information that will help. There are, however, ways students can cheat. Those who chose to cheat on quizzes obviously did not learn the material and it became

evident on the test. Tests have a much larger impact on the overall grade for the course. I often ask students if the goal is to get points on the quiz or to pass the test. What is more beneficial?

Conclusion

The activities in the TFY curriculum are not extremely different from the way chemistry is taught in other classes, which makes its implementation fairly accessible to all chemistry classrooms. Homework, calculations, quizzes, tests, and labs still remain the largest part of the course. The main change to the course is the focus of the instruction and the method in which material is delivered to students. Other strategies, such as online quizzing, are not significant of the TFY curriculum; they are just the way I conduct my class.

Teacher instruction plays a large role in chemistry due to the breadth of material. The angle of instruction is significantly different in the TFY curriculum. By angle I refer to the direction in which the instruction takes. The traditional angle starts with learning terms and a concept followed by the application of the concept, much like Bloom's levels of knowledge. TFY angle starts with the application, which students have witnessed in their lives and works back to the concept. The underlying theory is that, chemistry is everywhere, students already know it, and teachers just help students use chemistry to rationalize

what they see. The end result is the same, but the method and order of information acquisition is opposite.

Chapter VII: Evaluation of Think for Yourself

Introduction

The goals of the *Think for Yourself* (TFY) curriculum are that students learn to construct their own ideas, evaluate their own ideas, and gain interest through their successes. The TFY curriculum activities were used to guide students in each of these areas. Through this chapter I will present each of the goals, break down the data collection and data analysis with respect to the activities, and present the findings from the curriculum implementation.

Analysis of Goals

Conceptual writing and problem solving analysis are the primary activities unique to the *Think for Yourself* model. Supplemental activities, such as discussions, labs, quizzes, homework problem sets, were also used in the evaluation of the TFY model. The analyses of the goals presented utilize data from both the conceptual writing and problem solving analysis activities to a greater degree and compares them to data from the supplemental activities performed. Although the information covered through the major activities was based on the academic content standards for chemistry in California, the student product from the activities, written work, is currently not required by chemistry

standards. This is likely to change with the introduction of the common core curriculum (Common Core State Standards Initiative, 2010).

Goal 1. Students will improve their problem-solving skills through the practice and application of reflection of problem solving methods to both conceptual and procedural problems.

The use of prior knowledge and reflection empowers students to take control of their learning by applying, refining, and adjusting problem solving strategies. To become more self-reliant learners and problem-solvers, students practiced application of prior knowledge, reflected on process and personal theory to find gaps in reasoning, and worked to eliminate gaps through discussion and questioning. I developed and implemented conceptual writing (CW) and problem solving analysis (PSA) activities in the TFY curriculum as practice for self-directed problem solving and analysis. Data from these activities were analyzed to determine the effect, if any, they had on student's self reliance in other assignments containing conceptual and procedural problem solving situations.

Finding 1. Problem solving skills gained from the PSA activity did not transfer to other facets of the curriculum.

Originally, the reason for implementing the PSA activity was to increase students' self-assessment and reflection skills in solving problems. The use of reflection on problem solving strategies is a metacognitive skill requiring students to rethink and re-examine the methods used to perform calculations. Evidence of improved self-assessment skills would show increased scores in procedural homework and weekly quizzes through the course of the implementation. I collected evidence from the PSA assignments and compared it to the scores from the calculation-based homework and weekly homework quizzes.

Problem solving analysis data analysis.

The PSA is an assignment requiring students to reflect on their problem solving methods used as they break down their strategies for a specific calculation-based homework problem. I coded responses through the rubric shown below.

Problem solving Steps Laid Out	Not Present	Partially Complete	Complete
Description of Steps	Not Present	Partially Complete	Complete
Use of Math Vocabulary	Not Present	Partially Complete	Complete
Correctness of Vocabulary	Not Correct	Partially Correct	Correct
Explanation of Steps Taken	Not Present	Partially Complete	Complete
Correctness of Explanation	Not Correct	Partially Correct	Correct
Prediction of Correctness	Not Present	Predicted Incorrect Response	Predicted Correct Response
Accuracy of Prediction	Not Present	Inaccurate Prediction	Accurate Prediction

Figure 6. Data analysis rubric for problem solving activity.

I collected PSA responses and categorized the data into four subsets. Each subset is a combination of two lines in the rubric, as color coded above. Problem solving steps, vocabulary, problem solving explanation, and prediction of success were the subsets of the PSA data analysis.

I coded each row in the rubric as

- not present, absent from student work;
- partially complete or correct, student is missing or wrong in at least one instance (two instances for the explanation of steps subset);

- completely present or correct, student has included all requirements or is correct in all instances of the corresponding section.

For statistical analysis of this data, values of 1, 2, and 3 were assigned to codes of not present, partially complete or partially correct, completely present or correct.

The coding of each subset describes a different aspect of student work. The problem solving steps subset refers to student work shown in individual steps, written in an organized manner, and the accuracy of the method. The subset of academic vocabulary referred to the use of mathematical vocabulary in the explanation portion of the problem. The explanation of steps subset was divided into presence of an explanation and the accuracy of the explanation. The rationale for coding complete when missing one step was due to the simplicity of steps in the end of problems. I did not expect explanations for arithmetic methods of adding, subtracting, multiplying, and dividing in accordance with a formula. In the last subset, students, without knowing the actual answer, predicted whether or not they arrived at the correct answer. In looking through the homework I determined whether or not the prediction was correct.

To see the affect of the PSA on student problem solving skills and reflection I analyzed the explanation of steps and prediction of success subsets. These data subsets are both reflective parts of the PSA activity. In the explanation of steps, students provide reasoning for the steps they performed to solve the problem. Predicting success requires students to make a judgment on the work performed. Ideally, a self-reliant student would always predict success because they would work, research, and study to find the method of solving a problem.

Weekly homework quiz data analysis.

Each week students took a quiz as a formative assessment of understanding of content studied that week. Each quiz consisted of both procedural questions, and conceptual questions totaling 15 questions in all. Students take these quizzes online and have an unlimited number of trials. Each week, I graded the quizzes and graphed the total number of pass and fail attempts for the class.

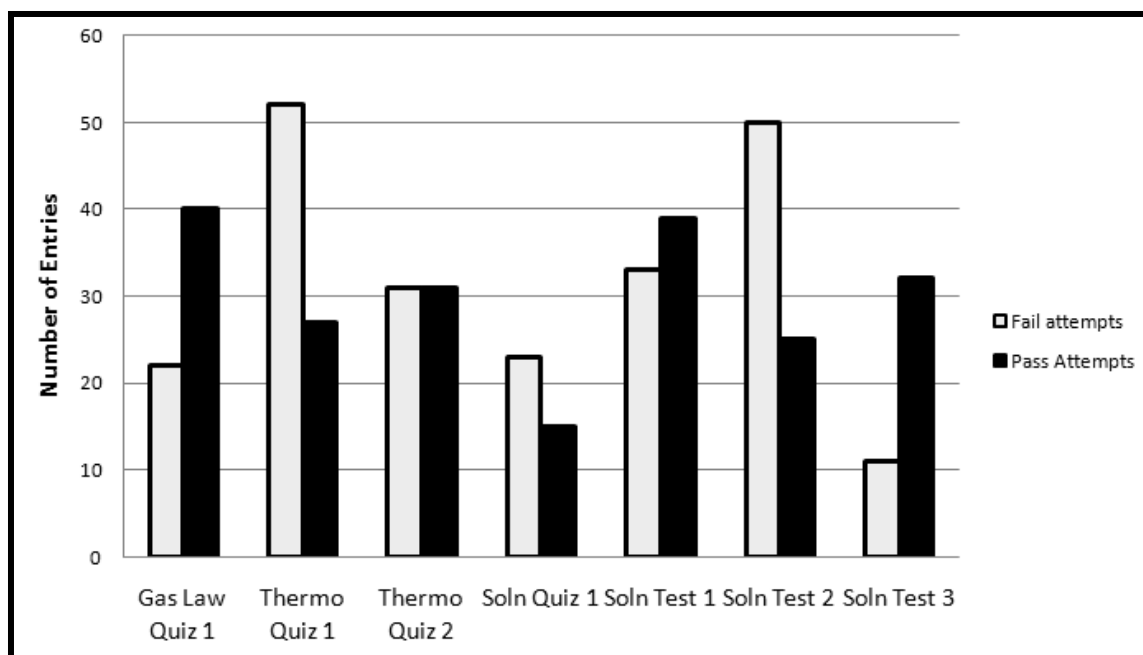


Figure 7. Total attempts for each quiz divided into pass and fail.

The figure above shows the results for each quiz taken throughout the implementation. The grey bar associated with each quiz depicts the number of attempts resulting in a failing score, less than 12 correct out of 15 total. The black bar associated with each quiz represents the number of attempts resulting in a passing score for the quiz. While the number of pass and fail attempts changes through the course of the implementation, there is no appreciable increase or decrease in the number of passing attempts. From this data I conclude that students are maintaining their level of proficiency on the weekly quizzes.

Students did not show an increase in the number of quiz submissions through the course of the implementation. To complete the weekly quizzes, students go to the provided link provided on the class website and take the quiz.

After completing the quiz, students can access their overall score and view the questions they answered correctly and incorrectly. With an unlimited number of attempts, further evidence of reflection is through the total number of quiz submissions.

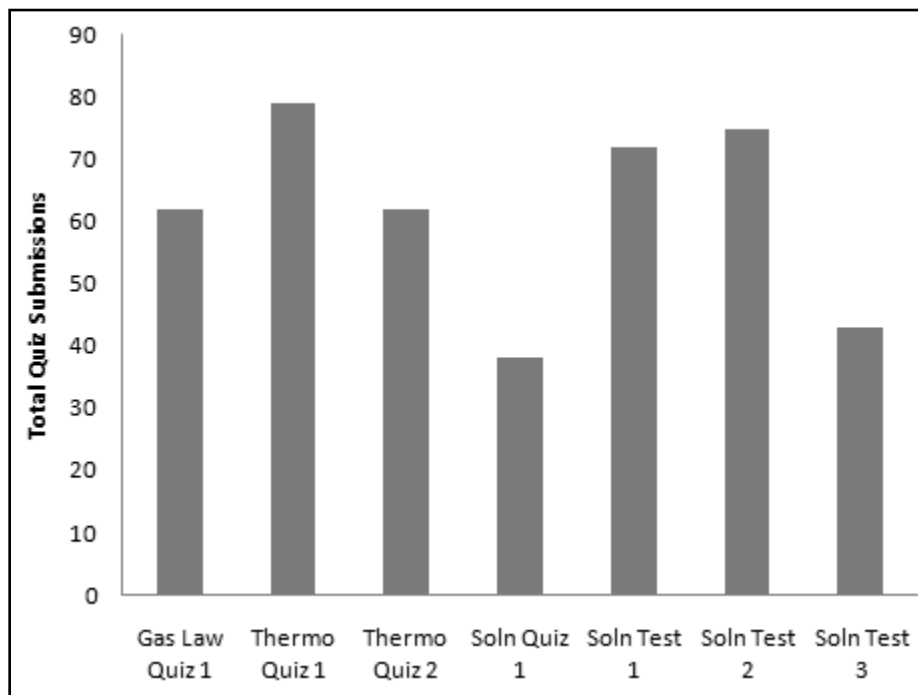


Figure 8. Total number of weekly quiz attempts.

The quiz data in figure 8 shows a fluctuation in the number of submissions moving chronologically, from left to right, through the implementation. While quiz submissions did fluctuate, there is no overall increase or decrease in the number of student attempts on quizzes throughout the study. Consistency of quiz attempts through the study is evidence of maintained self-reflection through the study.

Homework data analysis.

Although I grade homework based on student completion, I corrected homework for data analysis. Homework consists of between five and fifteen procedural calculation questions for student practice and requires a PSA for one problem in the homework set. I graded each homework for data and calculated the class average for percent correct.

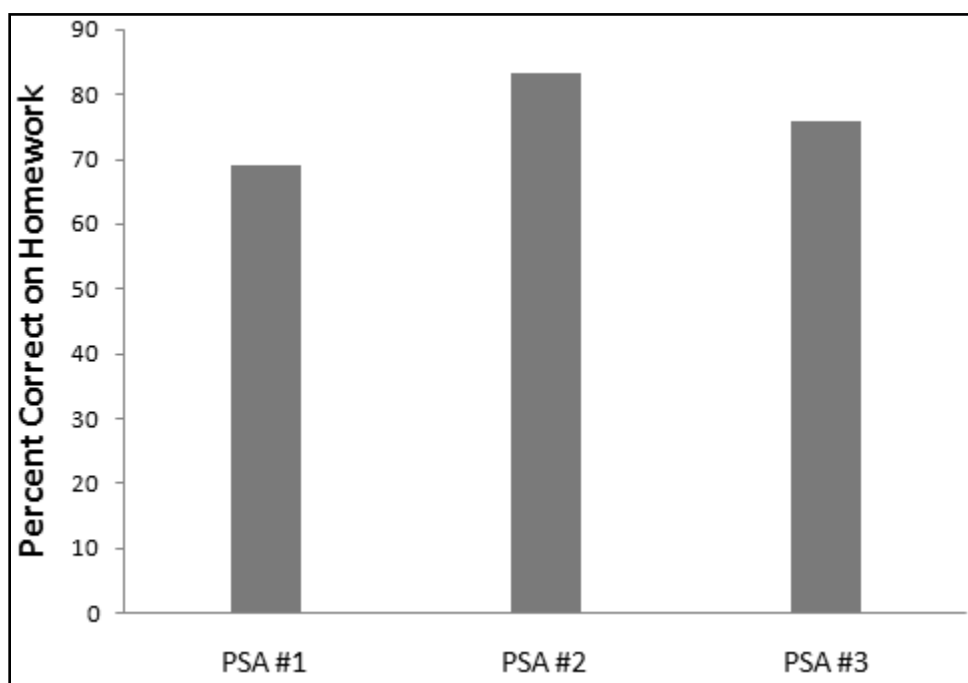


Figure 9. Average percent correct on homework assignments requiring problem solving analysis.

Analysis of class averages shows no significant increase in class average for percent correct through the implementation. The PSA data points represent the chronological sequence of homework assignments associated with PSA assignments. PSA #1 and PSA #2 were assignments two weeks apart, due to

class and state testing where PSA #2 and PSA #3 were assigned one week apart in accordance with the pacing of the curriculum. The class averages, shown in figure 4, show consistency in the percent of correct answers class wide through three consecutive homework assignments.

Conclusion of finding.

Analysis of PSA, weekly quizzes, and the homework showed no correlation between the practiced self-reflection and increase in self reflection skills. Evidence for this finding was limited by the amount of data collected due to the length of the study. Further, PSA activity completion, representing practice for student self-reflection occurred once per week, increased frequency of the assignment could alter the effect of the reflective practice on assignments.

It is important to note that although there was no statistical correlation between success on homework problems and completion of the PSA, students claimed their ability to solve problems increased. By informally interviewing random students, students told me that the process of analyzing a problem helped them to fix the issues they had and allowed them to ask better questions about the homework.

While analyzing the PSA data I observed that several students became more proficient as problem solvers. These lower level math students showed

slight increases in their math reasoning ability. Further study could determine whether this increase would continue due to the PSA or if the increase occurred from the repetition of mathematical procedures applied to new concepts in chemistry.

Goal 2. Students will be engaged in learning activities.

New curriculum, to be effective, must engage students. I am not referring to engagement as entertaining or fun, but that students are actively participating and learning. To analyze the affect of the TFY curriculum on student engagement I collected evidence to determine the affect of the TFY curriculum on student learning and participation through the analysis of student interviews and discussion webs.

Finding 2. Students increased engagement in chemistry content.

Through the course of the implementation students remained engaged in classroom activities as evidenced by their participation. In addition to the maintenance of participation, students changed the focus of participation to chemistry content, thus increasing student engagement in content. I assessed student learning through data from weekly formative assessment, discussed above, and student interviews. I collected evidence on student participation through the discussions held through the course of the study.

Student Interviews.

Student interviews provided evidence of student engagement. I conducted informal interviews at the end of each unit in my classes. I selected a few students, at random to ask about the test, the chapter, and the course. Student feedback helps me adjust instruction in the future and provided evidence of student learning.

Through the interviews held after each unit of the implementation, students expressed the ease of specific problems on the test. Students mentioned that, “some of the questions were just common sense” and “you asked the same question, like, three different ways.” In each of the quotes above, students referred to conceptual problems. The second quote refers to three questions on the gas laws unit in which three different situations were given in three different problems on the test. Each situation was an example of a gas law, Charles’s Law; however, to know that all three questions were the same, the student would need to understand the concept associated with Charles’s Law. Her comments were evidence that she was learning in class.

Conceptual Discussions.

I measured student participation through participation in both table and class discussions. In my classroom, students sit at lab benches accommodating

between three and five people. These groups are the table for the table discussions. Table discussions involve the negotiation of personal ideas, clarification, questioning, and concept building associated with the conceptual writing activity. Class discussions involve discussions amongst the entire class where I act as the moderator. Students ask questions, present ideas, argue points of view, and contribute to the overall classroom theory on a subject in class discussions. As discussed previously, in chapter six, to collect data on participation in discussions I had students fill out discussion webs.

Discussion webs provided evidence that all students participated in discussions. One student in each group tracked the conversation of the group. The students tracked discussions by starting a conversation with a dot on the web. The dot is placed next to the name of the student who starts the conversation. From this dot a continuous line is drawn to students as they participate in the discussion. Through discussion webs I was able to track participation by each student in the classroom in each table discussion.

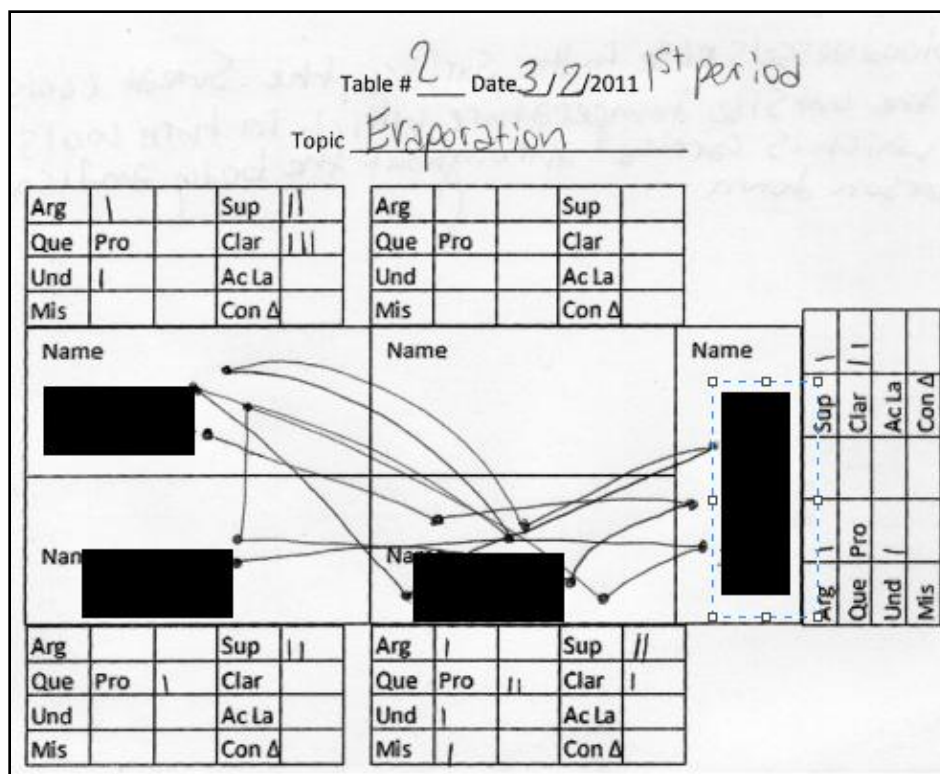


Figure 10. Completed table discussion web.

The discussion web in figure 5 shows the lines drawn between the participating members of the group. Each of the group members participated in the discussion. The student sitting in the bottom, left hand seat was the recorder of the discussion and only added two comments to the conversation, one of which started the conversation.

Conclusion of engagement.

Students provided evidence that they were both participating and learning through the TFY curriculum. Students provided evidence that they were learning content and concepts through student interviews and that they

were participating through both table and class discussions. Students were engaged because they were participating and learning. While unable to determine an overall level of engagement without a control group, I can conclude that the subject of engagement shifted. Evidence supports that students continued to be engaged in class activities; however, through TFY activities, students became more engaged in the content rather than engaged in the teacher or the participants in the discussions. Student engagement in chemistry content increased with the TFY curriculum.

Goal 3. Students will improve their ongoing development of scientific literacy as evidenced by their ability to effectively approach problems scientifically.

A scientific approach to solving problems follows the scientific method learned in school. Although the wording is different from the traditionally memorized form of the scientific method, the method itself is the same. Hypothesis, experiment, analysis, adjust hypothesis, retest, and conclude have transformed into three steps: form an idea, analyze and reform the idea, and develop a theory. The development of scientific literacy was analyzed on the ability of students to perform these three steps. Through the study these steps were operationalized through student work from the conceptual writing activity.

Through the conceptual writing activity, students practiced all steps in the scientific method. Students developed ideas by applying personal experience and prior knowledge to the problems presented. Having developed an idea of how to solve a problem or explain a solution, students performed an analysis of their ideas. Students, through group and class discussions, negotiated their ideas by combining, refining, adjusting, or completely rewriting their idea of how to answer the problem. Through this process and the constant challenging of ideas from both classmates and the teacher, students developed accurate scientific theories. The developments of proficiency in these areas lead to more specific findings regarding the TFY curriculum.

Finding 3. Students draw upon prior knowledge to build their understandings of scientific concepts.

I experimented with features of different activities in the TFY curriculum study. In the conceptual writing activity I experimented with the types of questions I asked students. Through the alteration of questions I collected evidence on the features of conceptual writing questions that support learning. Conceptual writing questions closely tied to prior knowledge and experience support student learning.

Conceptual writing question analysis.

I had students perform the conceptual writing activity to derive ideas that lead to chemical concepts. Chemistry is an empirical science, in which theories are the explanation of many observations. Conceptual writing relies on the use of observations for students to build their ideas, personal theories, and, later, develop scientific theories.

In writing conceptual reasoning prompts I found there were two structures in which to construct prompts for student response. Students wrote easily for conceptual writing prompts that questioned the common are we missing a word here? and lead students to content. Students performed poorly on conceptual writing prompts written in the context of content and while eliciting common observations in student responses. If prompts are grounded in theory more than experience, students have difficulty with the meaning of the question and are unable to apply appropriate concepts.

When students explain their experience or an observable phenomenon, they can construct concepts. Through the study, students developed conceptual understanding by explaining common situations. I asked students to explain why a sugar cube takes a longer time to dissolve than an equal amount of grain sugar. Through the process of answering and discussing this question, students developed the collision theory for chemical kinetics. Students did not relate

prior knowledge to concepts when I asked them to provide explain a situation not explicitly related to prior knowledge or experience. The language of the question was too academic and students struggled to understand the question, and responses did not get to the application of correct concepts.

I asked students to explain how evaporation can be considered both endothermic and exothermic. I asked students this question for homework after one day of writing and discussing the phase changes of matter and the terms exothermic and endothermic. I thought students would be able to answer the question using the ideas discussed in class that day. The day homework was due students began discussing the question even before prompted. By listening in, I heard students expressing confusion, few even had an answer and those who did were not confident in their answer. Upon checking the answers I found that only nine of the 23 completed assignments used any conceptual reasoning.

After checking the homework, I presented the question in a different manner to spark a productive discussion. I asked students to explain how sweat cools the body. Sweat cooling the body is a practical example of evaporation both absorbing and releasing heat. Students rationalized the phenomenon by offering the idea that excited, high energy sweat molecules evaporate, leaving slower moving, cooler molecules on the skin causing a cooling effect.

Despite the discussion and conclusions drawn from the question I was worried that students did not have the chance to work through the question alone. Responses were constructed out of the class setting. Although I prefer a collaborative class, I also prefer students to think for themselves prior to having collaborative efforts to come to an answer.

At the end of the week students took the weekly homework quiz. Of all the quizzes in the study, this quiz had the lowest pass to fail ratio. For the total number of trials on the quiz, there were almost twice as many failed attempts (53) as there were passing attempts (27). Of the questions on the quiz, eleven were directly related to heat transfer and phase changes, a subject covered with the evaporation question and the sweat question. The performance on the conceptual writing activity for the week and the conceptual understanding displayed through the quiz scores supports a lack of conceptual proficiency through the week and a lack of understanding through the structure of the conceptual writing prompt.

Conclusion of finding.

Students use prior knowledge to generate concepts more easily than they use concepts to generate a prior experience. By asking questions about prior experience, students can answer the question specifically and then generate a

more general concept from the answer. The example above showed how students failed to relate a general concept question to a prior experience.

The two questions, on the same topic sparked different levels of engagement. Students were confused and unengaged with the question on evaporation, which resulted in unconfident answers and a collective silence. The question on sweat sparked a conversation involving many students and the concepts of heat transfer and phase changes. In each response, students mentioned evaporation. Further, teachers can control the change in student knowledge with the writing prompts presented to students.

Teachers can manipulate the use of prior knowledge through the TFY curriculum to lead students to scientific theories. Students continually learn new concepts in any class. What is new one day is prior knowledge for the next day. In the TFY curriculum, I used the conceptual writing prompts to continually assess and alter students' current theories. Students responded to prompts by adapting their theories with the observation. As I challenged student theories with further situations and questions, students adapted their theory to match multiple phenomena. I carefully chose writing prompts to challenge specific aspects of students' theories to lead to specific adjustments to students' theories.

Through the careful choice of questions, I was able to lead students to more correct scientific theories.

Finding 4. Students' understanding of scientific concepts does not depend on their use of academic vocabulary to communicate their ideas.

I commonly ask students to explain situations they encounter outside of class for the purpose of concept development. "What happens to a helium filled balloon after the little kid let it go outside?" "Why does wind blow toward the ocean in the morning and toward the shore in the evening?" "Why does hot water dissolve sugar faster than cold water?" are questions I asked in the study of the TFY curriculum through the conceptual writing activity. These questions exemplify possible experiences for students and I require students to answer them with nothing but experience and prior knowledge. As discussed in chapter six, I use keywords to provide minimal direction for students. The keywords are from the required vocabulary from the chapter and often provide students with hints to the conceptual nature of the question.

Conceptual writing data analysis.

Through the conceptual writing activity I collected data on concept development. I analyzed student work from the conceptual writing activity for levels of conceptual reasoning and the use of academic vocabulary.

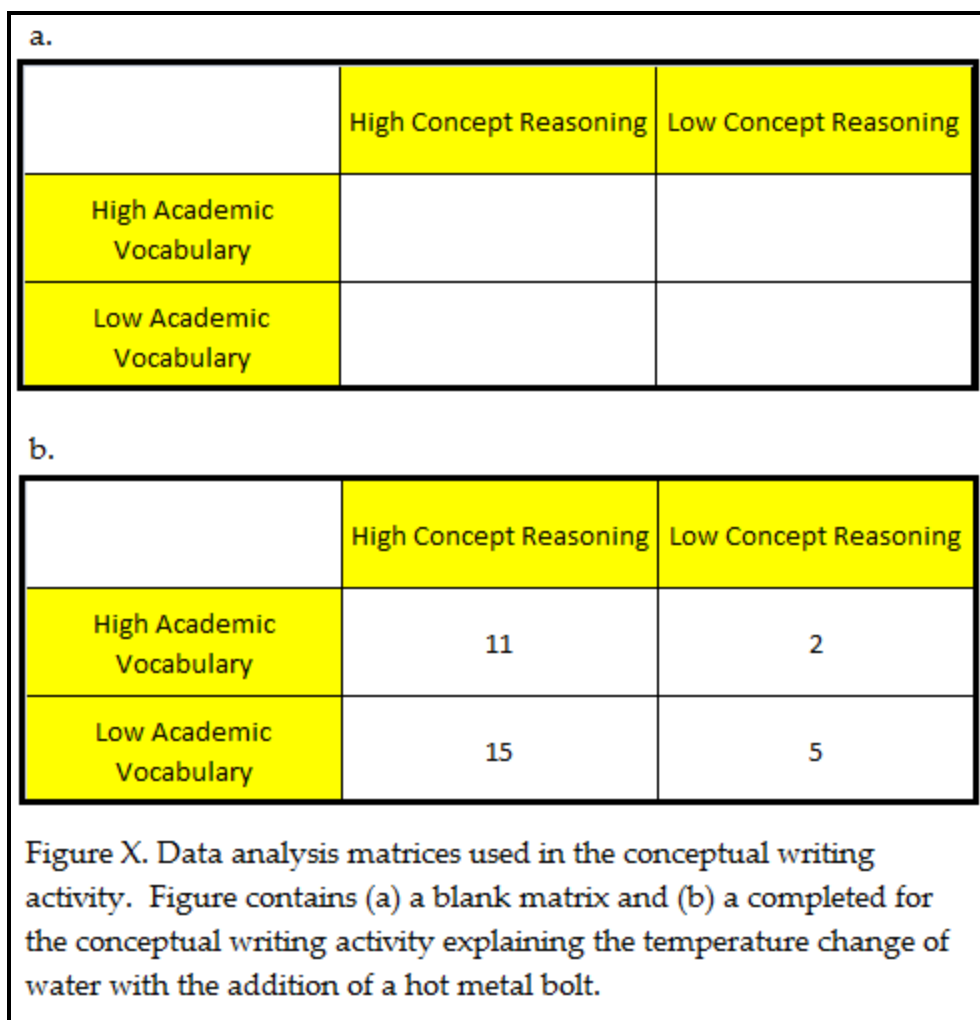


Figure 11. Data analysis matrix for the conceptual writing activity.

I used the data matrix shown above to divide papers by the level of academic vocabulary use and level of conceptual reasoning. With each paper I placed one tally mark classifying the paper by both academic vocabulary and conceptual reasoning. To clarify, the completed matrix in Figure 11 shows eleven papers classified as high academic vocabulary and high conceptual reasoning, fifteen papers were considered low academic vocabulary and high conceptual reasoning.

To differentiate between vocabulary levels, I defined *high academic vocabulary* as a paper containing two or more academic vocabulary words. I did not limit academic vocabulary to the keywords given with the problem; however, these were the most common academic vocabulary words used. Further, irrelevant academic vocabulary or misuse of relevant academic vocabulary did not contribute to the overall total.

I defined *high conceptual reasoning* as the use and expressed relationship of the situation described to a scientific concept. Student responses that used an appropriate concept were categorized as high reasoning responses. High conceptual reasoning responses did not require a correct answer, only the application of one or more concepts.

The correct answer is not the only judge of high reasoning. In reading through the conceptual writing papers I observed some students would use good reasoning without getting close to the correct answer. In response to this observation, I began to look for both concepts applied and the presented relation to the situation. Students produced three types of conceptual responses. One, students wrote a concept, but did not relate the concept to the situation. Regardless of accuracy, I classified writing a concept without reasoning as low conceptual reasoning. Two, students wrote about a concept and related it to the

situation. Regardless of accuracy, I classified the relationship of the concept to the situation as high conceptual reasoning. Three, students applied conflicting concepts to the situation, pointing out why both concepts apply and how they contradict, but did not form a definite conclusion. I labeled these responses as high conceptual reasoning.

Conclusion of finding.

Through the analysis of five conceptual writing analysis activities there was no relationship between the use of academic vocabulary and conceptual reasoning. Students who used high levels of academic vocabulary were not more likely to exemplify high levels of conceptual reasoning. I concluded this after noticing the large number of papers classified high reasoning and low vocabulary in the data matrix. Data in this region represents an explanation in everyday language.

Data from the conceptual reasoning activity supports that academic vocabulary is not a prerequisite of conceptual reasoning. The conceptual writing activity requires students to use prior knowledge and experience to develop an idea, in this case explaining a situation. A large number of students adequately explained their ideas, experiences, and prior understandings through everyday nonacademic vocabulary. In the discussion, following the written portion of the

activity students heard the same descriptions repeated, and often asked if there was a word for the description. For example, in describing why hot water dissolves particles faster than cold water, students wanted to know, “is there a shorter way to say that the particles move around faster because it’s hot?” From this question, the students learned the definition and relationship between the terms temperature and kinetic energy. While student’s conceptual reasoning was not dependent on academic vocabulary, students often sought the vocabulary, after writing explanations, to make them more succinct. In doing this, students learned the academic vocabulary associated with topics covered. Academic vocabulary, taught in this manner, was less of a burden on students and more of a sought learning activity. Through this, students learned the vocabulary associated with concepts through use and application rather than memorization. Vocabulary is then organized under a concept rather than the corresponding chapter of the text book. Further, students presented concepts in a manner more closely aligned with the scientific community.

Finding 5. Students grew in their consideration of alternate explanations by reflecting on the possible deficiencies in their own conceptual reasoning.

To further develop an idea into a theory, students needed to collect evidence, test, and refine their own ideas. This process, making up the second step of the scientific method, developed through student discussions of student generated ideas. Students participated in conceptual discussions immediately following the conceptual writing activity. Through the discussions students read other student explanations, explained their own ideas, listened to alternate explanations, and discussed the plausibility of all explanations with others. Initially, students would listen to, but did not accept, alternate explanations.

Conceptual discussions provided a forum for students to find gaps in their own reasoning and negotiate new ideas and theories. Prior to whole class discussions, groups would have table discussions. As tables discussed I walked around and made notes of the explanations and arguments I heard. In class discussions, after students presented a popular idea, argumentation stopped. In playing devil's advocate, I would point out alternate explanations and valid points of view. In the beginning of the study, students laughed as I, or another student related an alternate explanation to the class.

As the study continued I observed a change in the acceptance of abstract and alternate explanations. Students would seek validity in absurd explanations and use alternate ideas to find gaps in their own reasoning. Students became disappointed when alternate explanations were not presented. What started as laughing at somebody else's wrong explanation turned into an analysis of how the explanations could be considered the same, how they conflicted, and what principle would determine who was correct.

Conclusion of finding.

Through the acceptance and analysis of alternate ideas students became more able to construct scientific theories. As student consideration of alternate points of view increased, students considered different relationships and variables in explaining situations and reforming ideas. Through the reformation and refinement of ideas, students developed the ability to analyze ideas without bias, and began to construct scientific theories covered in the textbook.

Summary

The Think for Yourself curriculum consisted of implementing three flexible activities to enable students to improve problem solving skills, increase engagement, and improve the development of scientific problem solving in chemistry. Students practiced self-regulation of problem solving methods

through the problem solving analysis activity, the written student reflection for solving procedural problems. Students constructed scientific theories by responding to conceptual writing prompts and negotiating ideas with other members of the class in conceptual discussions. Through problem solving analysis, conceptual writing, and conceptual discussions students constructed content knowledge from prior knowledge. I had students complete these activities to study the affect of the TFY curriculum on developing self-sufficient learners.

The overarching goal of the Think for Yourself curriculum was to develop students as self-sufficient learners through writing activities. The TFY curriculum is based on research and best practice methods for instruction. Each activity in the curriculum was studied to observe the affect of TFY activities on each of three specific goals. The specific goals for the curriculum were

- to improve student problem-solving skills and the reflection of problem solving methods for both conceptual and procedural problems,
- engage students in learning activities,

- and improve the ongoing development of scientific literacy as evidenced by student's ability to effectively approach problems scientifically.

Through the curriculum, students are challenged to restructure the knowledge they already have to align their personal theories with the scientific theories covered in chemistry content standards (Marzano, 1991; Common Core State Standards Initiative, 2010; Curriculum Development and Supplemental Materials Commission, 2000). Conceptual writing and conceptual discussions were the activities implemented to access and restructure prior knowledge. Through the conceptual writing activity, students communicated personal theories through written responses to analyze common observations. Students created explanations of phenomena in their own words and developed preliminary ideas. Through the conceptual discussions, students discussed their ideas, argued their points of view, and negotiated the plausibility of their explanations to come to a more accurate theory (Vygotsky, 1986; Wells, 2007; Wink and Putney, 2002). As a mediator of classroom discussions, I challenged these theories to help students fine tune group theories and develop scientific theories (Marzano, 1991).

Students restructure knowledge and construct theories through a writing to learn method that conceptualizes and organizes details under big ideas rather than scattered facts (Langer, 1986; Rivard, 1994; Schneps, Crouse, Harvard University, Smithsonian Institution, and Project STAR, 2002). By developing theories through a cognitively demanding task, writing, students internalized the concepts (Langer, 1986; Rivard, 1994). Combined with the discussions, these teaching practices are beneficial and demanding for both high performing and low performing students (Rivard, 1994).

Through the scope of the TFY curriculum, students participated in the scientific method and developed concepts useful in day to day life. I made participation a requirement in the class by implementing methods of instruction and shift of responsibility from teacher to student. Through formative assessment, weekly quizzes and homework assignments, students displayed learning material. The combination of participation and learning was evidence of student engagement through the curriculum. By participating in the scientific method of producing ideas and restructuring ideas into scientific theory students developed their ability to solve problems scientifically. The metacognitive skills of reflection and self-regulation developed became evident as students sought alternate explanations and altered theories to fill in gaps in their own reasoning.

The TFY curriculum succeeded in all three goals of the study. Students developed in their willingness and ability to apply prior knowledge to problems and reflect on the problem solving process, students remained engaged in the learning activities, and students developed their ability to approach problems scientifically by forming a hypothesis, testing it against competing ideas, and coming to a well informed and accurate conclusion.

Chapter VIII: Conclusions of Think for Yourself

Despite my fears that the *Think for Yourself* (TFY) model, when implemented in a chemistry class, would require more time to complete and hinder the covering of all pertinent standards, the approach was successful, and did not in fact require more time or prevent coverage of the standards. Students performed a significantly larger amount of writing than other physical science classes in my high school. Students wrote in response to questions and observations they may have wondered about or observed through the course of their lives. Students wrote about their problem solving process. Even while performing quantitative work, they were required to write about their method of solving the problem and analyze this method for reasons why they performed each step and whether their method was correct. While this amount of writing added to the time spent on specific subjects, the pace of the course was not affected.

The activities of the TFY model allowed students to display proficiency in material by integrating and constructing concepts. I asked students questions pertaining to a specific concept. Students integrated several concepts to analyze the question. Even if the answer was incorrect, the use of the content and prior concepts demonstrated a mastery of previous material. Further, the ability of

students to apply their ideas of concepts not yet covered in the course allowed for discussions that covered material presently being discussed as well as concepts covered earlier and later in the course. I attribute the speed with which we moved to these discussions, even with the extensive time used for writing and discussing ideas of a single question or observation.

The incorporation of multiple concepts and ideas, in writing, for the purpose of explaining an observation is not required of students by current standards, and neither is the written self analysis of problem solving methods. Currently, education is in the beginning stages of shifting from the state content standards to a common core curriculum. Chemistry students, as a consequence of this shift, will continue to learn chemical content and concepts, but the focus will shift from learning content to learning to think critically and communicate content effectively. Presently the focus in chemistry is learning for the sake of learning. Occasionally interest is developed and students continue to pursue chemistry in high school, but seldom continue to study this in college. The shift of the content in chemistry curricula, as in the TFY curriculum, is to teach students skills: communication of ideas, critical thinking of complex processes, and problem solving strategies. While the content may stay the same, the underlying goal of students taking the course shifts.

Why take a subject that you are not going to study in the future? A question frequently answered with, “How do you know you are not going to study it in the future?” The TFY curriculum provides a different answer, a more practical one. Students take science to learn to solve problems, construct theories, test their theories and communicate their results to others just as students take English to communicate and understand the communication of others, and students in social science learn about the decisions, judgments, mistakes, and successes of the past to make more informed decisions in the future.

Shifting to the TFY curriculum and methods aligns chemistry instruction with research in developing critical thinking through metacognitive practice. TFY goals match the goals of the common core curriculum and places them in a scientific context. TFY activities do not sacrifice the content of chemistry; in this study, the coverage of chemical concepts and the display of understanding has increased through the TFY implementation. To complete the writing assignments students combined the theories from multiple chapters creating cohesion rather than disjointed ideas in sequentially ordered chapters of a book.

Spreading the TFY curriculum

I did not expect the teachers at my school to oppose the TFY model as much as they did. While one teacher in my department questioned the activities and sought to help me improve them, other teachers of chemistry, physics, and biology opposed the use of writing in their science classrooms. When questioned about the reason for the new curriculum I explained the research in support of the method and my initial findings. I received responses that pointed out the difference between what researchers say and what works in the classroom.

Having been on both sides of the research versus experience argument I can see the point the teachers made. As a teacher, I know research does not always mesh with classroom situations. Personally, I have found research that supports my methods of teaching as much as I have found research that condemns it. Research is not classified as right and wrong.

The point of research is not to create a one-size-fits-all approach to teaching. There is not an answer to how teachers should teach. As a researcher, I analyzed a curriculum in my classroom, with my students, and led by me, and the data I collected supported the success of the curriculum. These results will not translate to every class and every teacher. Research, when read correctly is a negotiation. In the TFY curriculum this negotiation would be a conceptual discussion with argumentation, support, analysis and adjustment.

The only reason I can understand both sides to the argument is because I am a teacher and a researcher. With my experience as a teacher-researcher I have concluded only one certainty in educational methods and research; good instruction is effective and bad instruction is not. Knowing this I am willing to study and research different instructional methods so I maximize my effectiveness as a teacher and provide research to others so they can improve their practice.

This is not the perfect curriculum. I taught my students through the activities of the curriculum that ideas and methods need to be analyzed, argued, challenged, and adjusted. Through the development of the TFY curriculum I have become a participant in the method by which I teach. Though this curriculum contains some inadequacies, it is also filled with genius. Like the students in my class found with explanations of common observations, it is possible to get the same answer from two different methods. The TFY curriculum is an alternate method of teaching chemistry: adopt it, reject it, or challenge it to make it better.

Appendix

Think for Yourself:

A model of writing in chemistry

By John Morgan

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Letter to the Teacher

Dear Teacher,

This section of the paper presents the activities of the curriculum within a week-long plan. While the plan is the exact implementation plan I used, this is not the crux of the curriculum. The conceptual writing, conceptual discussion, and problem solving analysis are the activities unique to the curriculum. The schedule-based presentation gives context as well as examples to make the activities more clear.

The most difficult portion of this curriculum is getting started. Personally, I was scared that, with the method of teaching I suggest, I would not cover material in time for state testing and that students would get lost more than they would learn through the questioning process. Once I decided to implement this curriculum I was surprised by how fast the students moved through the material.

Students covered more material and learned concepts through their own discovery. When I present students with an observation, I know how I would explain it and what concept it covers. The class members would relate concepts I had never thought to consider. Through questioning, discussing, and testing they learned both the concepts I wanted them to learn as well as other concepts

students applied to the writing prompts, this was the reason the class moved quickly. Towards the end of the year, students had already learned the material.

The most enjoyable part of this curriculum is the practicality of the examples and the explanations presented by the students. Students presented explanations that, at first hearing, appear ludicrous; however, with careful examination, these explanations can be found somewhat accurate. As a teacher, the difficult part of the curriculum is challenging explanations to help students develop a concept.

Teachers guide students by restructuring knowledge. To convince students to change their explanation, the explanation must be challenged and shown inadequate. By challenge, I am referring to the questioning an explanation with a different observation. A student proposes an explanation and after discussions I chime in with, "Yes, but how does that explain ...". Challenging students is difficult, but also fun and engaging for both teacher and student.

Please enjoy responsibly.

Introduction to the TFY Curriculum

The curriculum presented through the following pages is a simple set of activities designed to increase conceptual reasoning ability and problem solving

ability in a science class. I implemented the presented examples in a high school chemistry class; however, educators may easily manipulate them to support scientific learning in other high school science classes. The *Think for Yourself* (TFY) model aims to build students reasoning abilities. The curriculum objective is to support students in becoming self-sufficient science students, hence *Think for Yourself*. This main goal is supported through three specific goals.

- Goal 1. Students will improve their problem-solving skills through the practice and application of reflection of problem solving methods to both conceptual and procedural problems.
- Goal 2. Students will be engaged in learning activities.
- Goal 3. Students will improve their ongoing development of scientific literacy as evidenced by their ability to effectively approach problems scientifically.

The TFY model teaches students to use their common sense in situations they see every day in and out of the classroom. Students use their prior experiences to break down and rationalize situations presented to them in the classroom. Through in class practice students begin to apply the science of the classroom to their lives outside the classroom. By presenting them with authentic learning experiences and providing classroom support to analyze,

break down, and build conceptual ideas about the real world, students are able to derive the concepts normally spoon-fed to them through lecture. In the problem solving analysis portion of the curriculum, students break down the problems they were assigned. Students lay out the steps used and rationalize their use in the overall process.

The preparation for the activities is minimal and requires little scaffolding for students to grasp the idea and point of the tasks. Through these activities, students are required to use both their prior knowledge and learned problem solving methods. Students already have these tools by being present and active in the class. The use of the TFY curriculum is the application of prior knowledge and analysis of problem solving abilities.

As a byproduct of the written responses, students can also learn to write academically. Through modeling academic writing, I have found students pick up and use the writing style presented early on in the curriculum. I have taught students to explicitly state their conclusion and then add supporting sentences that provide either documented or experiential evidence for the conclusion reached in the topic sentence.

Weekly Plan with Activities

I used the following schedule in my class as a mold for each week. The schedule creates a routine and ensures differentiated instruction for students of different learning abilities and language proficiencies. The schedule used fits into the schedule for my current high school which is a combination of traditional schedule (all periods taught in a single day) and block schedule (longer periods when specific classes meet every other day). For example, I see all of my classes on Monday, then on Tuesday and Thursday, I see my odd period classes and on Wednesday and Friday, I see my even period classes.

The activities used in the course are scattered through the overall plans for each day. By organizing the curriculum this way, I hope to place the activities in the context and flow of the week and move from students' currently held theory to accepted, scientific theory. When these activities are used is as important as what they emphasize.

To further clarify the structure of the course, Figure 12 shows the weekly activity structure for the TFY curriculum. By following this template I find I can manipulate activities and fit them into the week in a way that supports the structure of the class and provides a routine.

Time	Monday	Wednesday	Friday
0	Intro - Question posed to group _ Discuss and explain w/ Chem if possible	Pass and Read Explanations	Pass and Read
10	Report on explanations	Discuss Writings as group Discuss Writings with Class	Discuss Solutions as a class
20	Mini-Lecture - Introduce concepts and variables _ Focus on relationships _ Cell Phone Questions -		Discuss Lab and solutions
30	Formative Assessment	Activity - Lab _ Quantify an Observation	_ Extra time if necessary
40	Restructure Knowledge - Re-evaluate explanation	_ Use Qual. In Lab to relate Quantified Info	Review Concepts for the week
50	HW - Writing Prompt - Explain a phenomena		_ Relate Concepts to problems _ Problems with calc's and explanations _ Work as group _ Go Over Problems
60			
70		Mini-Lecture - Introduce Equations - Quantify _ Sample Problems	Developing New Connections _ Give new situations where concepts apply _ Give time for talk and Explanation
80		_ Work Problems as groups	
90		Go Over Problems on Projector	
100		HW - Problems - Pick 1 to explain soln& Reason	HW - Quiz over weekend - Google Docs

Figure 12. Weekly schedule of activities the TFY implementation.

My School Schedule:

Mondays are 52 minute periods. Wednesday and Friday are 100 minute block periods.

Lesson plan template.

There are several pages to the Lesson Plan. The first page is the actual lesson plan and the other pages are discussion webs for each of the periods. I tend to write all over them through the course of the day.

I designed the following lesson plan template to be a working lesson plan. I constructed this model from the frustrations I have with other models I have seen in the past and have therefore added a few things.

- First, I organized the lesson plan with tables rather than with paragraph style. This makes the lesson plan easier to follow when in front of a class. I can glance quickly at the plan rather than read the plan.
- Second, I placed a preparation section in the lesson plan so I have a checklist of what to make for the class. (copies, PowerPoint, etc.)
- Third, there are more aspects to teaching than just what you plan will happen. For this reason, I have added both a reflection section and a discipline section.
- The reflection section is a way to make notes on acts of brilliance that only comes when teaching, write it down and add it to the plan for next class or the same lesson next year.

- The discipline section is for class management issues. Administrators always want documented proof of what a student is doing and whether or not the teacher called or emailed the parents. That is the point of this section. Mark it up.
- The other pages of the lesson plan make the discussion section. The discussion section of the lesson plan is made of the discussion web. I began using the web with concept discussions to model discussion webs in my classroom. I have expanded the use to all discussions taken place in the class. This discussion web is special for my classroom, which is set up with eight tables of between four and five students. Teachers can make their own with a photocopy of a seating chart. Many times, I will project the discussion web on the board and use a sharpie to fill it out so students can see what I am doing. Students have said they like seeing that I am listening and taking notes on what they have said. When the discussion is over, I can summarize the conversation with the input from all of the groups.

Lesson Plan Template

Day: M T W Th F **Date:** / / **Title:**

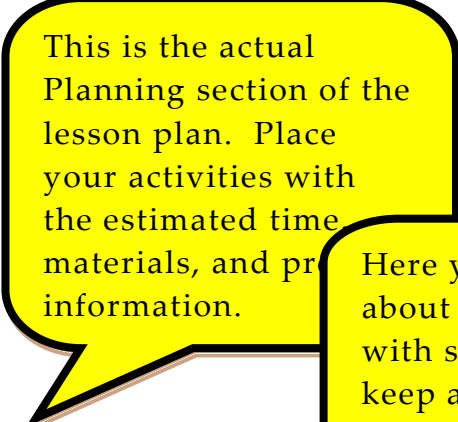
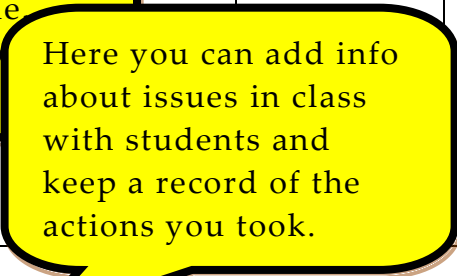
Purpose:

Objectives/Standards:

- TSWBAT (The Students Will Be Able To...)

-

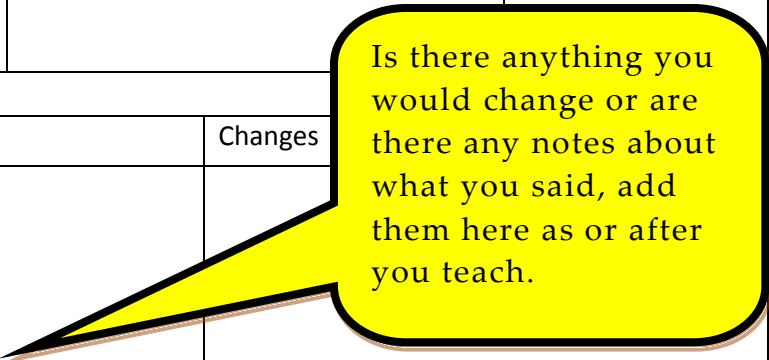
Schedule:

Time	Activity/Description	Materials	Prep
	 		

Discipline:

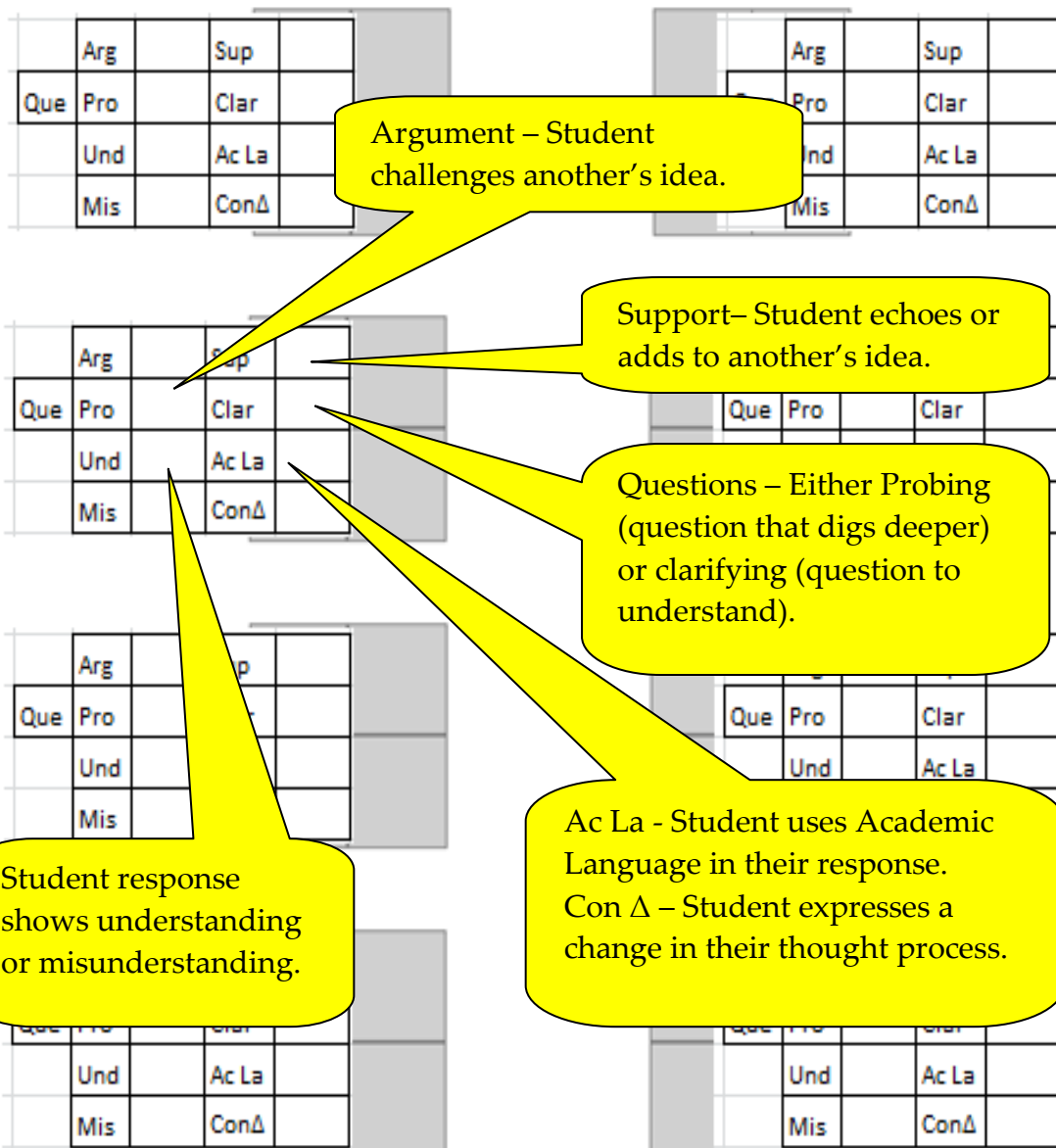
Period & Student	Issue	Result

Reflection:

Notes	Changes
	

Discussion Notes:

Topic _____



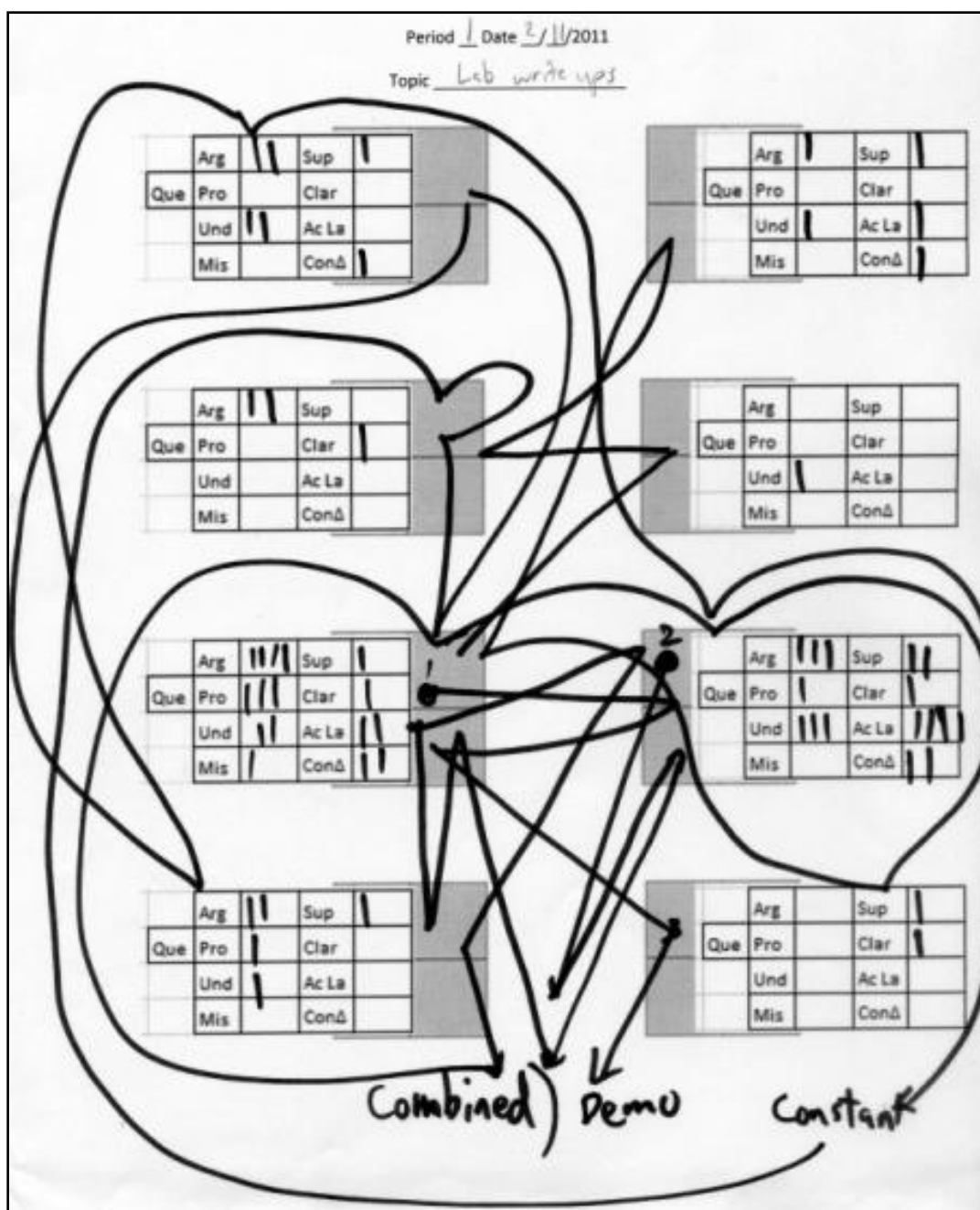


Figure 13. Class discussion web on the soda can crushing lab.

Filling out the discussion web.

When a conversation starts place a dot next to the place it begins. From here, draw lines from the person who spoke to the person speaking. Continue doing this with each additional comment from different students, as the conversation progresses it will become clear why this is a web and not just a chart.

Monday, 52-minute traditional period.

Monday, the first day of the weeklong cycle, is a conceptual learning day. These days are void of numbers and full of theory. I focus instruction on the development of concepts used throughout the week. I do not directly teach these concepts to students; they come up with their own theories through rationalization and conceptual writing. This is the first activity used in the weeklong progression.

I have given a generic lesson plan for a Monday class. I have left off the discussion web; this does not change from the generic lesson plan given above. Monday classes are 52-minute periods and, as stated, I have structured them as conceptual learning days.

Monday Lesson Plan Template

Day: M T W Th F **Date:** / / **Title:**

Purpose:

Objectives/Standards:

- TSWBAT

-

-

Schedule:

Time	Activity/Description	Materials	Prep
10	Conceptual Writing (CW) – prompt		Ppt
10	Conceptual Writing Discussion (CD) – read – discuss – report		
15	Lecture (L) – cover concepts for the week.		Ppt
5	Cell Phone Question (Cell) – question		Cell Q
12	Conceptual Reasoning Homework (CHW) Prep –HW questions and expectations.		HW, Copy

Discipline:

Period & Student	Issue	Result

Reflection:

Notes	Changes

Conceptual writing activity.

Students begin class with a conceptual writing entry task. Usually presented to the class in a PowerPoint presentation, the prompt consists of a question or observation either directly told to students or shown to them with a combination of pictures and video. Students write a response to the prompt applying what they know, their creativity, and critical thinking. Students write individually so students can follow their personal train of thought. They will then share them in their group and discuss them before sharing them with the class.

The key to the conceptual writing activity is the question or writing prompt presented to students. The use of conceptual writing in the TFY approach is to build concepts from prior knowledge. These prompts are given before any content is covered in class. Therefore, the questions require the assumption of no prior knowledge; they must be familiar to students. Familiar is not to be confused with easy. Questions can be conceptually difficult without being content dependent.

The first example of this uses the pictures given below where the relation to chemistry is easily seen (Gas Laws). Students explain how the gas tanker imploded.

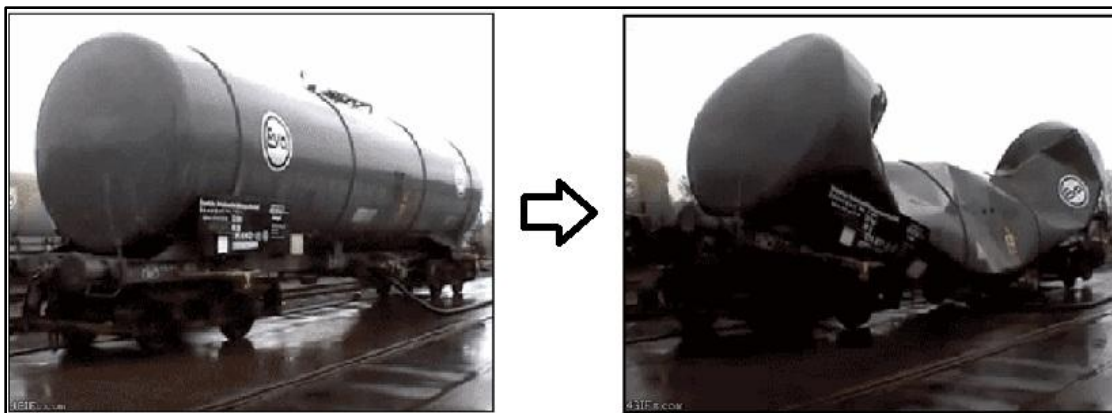


Figure 14. Train tanker that implodes without physical contact.

I let students know that no person has touched this tanker or influenced the actual crushing. Explain how this happens. From this prompt and the subsequent written explanations students hint at ideas of proportionality whether direct or inverse and use terms like pressure, temperature and volume without prompting. Although there are many misconceptions with these ideas, the discussion can help students to reshape their own ideas.

The second example is a question that seemingly has no chemistry connection. Students negotiate how to trade at the lunch tables to get the snack they want.

YOU HAVE 2 POPTARTS BUT YOU WANT HOT CHEETOS.

- You go around the lunch tables and research what each person would trade their snacks for.
- You compile a list of what every person has and wants.
- Figure out how you can turn your popartars into hot cheetos.
- Write out your steps.

1

NAME	HAS → WANTS
○ Voldemort	cookies → ding dong.
○ Albus	Hot Cheetos → oreos
○ Hermione	honey buns → Moon pie
○ Ron	chips → cookies
○ Harry	ding dong → honey buns
○ Hagrid	Moon pie → Poptarts
○ Severus	oreos → chips

2

HOW DID THIS PROCESS...

- How did you make this work?
- What does this mean about a simple trade of popartars for hot cheetos?
- What do you think this has to do with chemistry (not nutrition).
- In your writing, use the terms feasible and state function.

3

Figure 15. Conceptual homework writing prompt that lead to a discussion on Hess's Law.

The students are able to answer the questions because they are familiar with the process of trading and can relate to the scenario. The discussion is more important in this case as the idea of trading lunch snacks evolves into a discussion on state functions, the emphasis on the beginning and end rather than the path. This problem then evolved to a discussion on Hess's Law, and thermochemical equations. The question proposed to the students is presented to the students in a PowerPoint, shown below.

Conceptual writing discussions.

To maximize the effectiveness of the activity, students are encouraged to use each other's ideas and knowledge to generate the best answer possible.

- Students, in sets of three to five, engage in table conversations to read, argue, support, help, and listen to rationale on the topic. The focus of the conversation and writing is not on academic language but rather the thought process involved in explaining observations familiar to high school students.
- After about five minutes of the group discussion groups summarize their discussion with a written one to two sentence summary/description about their conversation.
- The written summary is then shared with the class. This written summary of the conversation is particularly important. When students in my class were asked to share, they had a tendency to say, we basically said the same things the other groups said.
- Written summaries allow groups to report identical information. An alteration in wording often brings out misconceptions, leads to deeper understandings, or inspires class conversations on similar topics that can be explained with similar conceptual application.

As the teacher, I have the benefit of being the mediator of the class-wide conversation and can steer it in the direction that fits the best interests of the class. When I do this correctly, the notes presented feel like review for students. This reduces the time necessary for understanding and leaves more time for interesting discussions and questions.

Conceptual writing homework.

Monday lectures are a quick synopsis of topics covered in discussions and present new vocabulary. I keep lectures to ten to fifteen minutes. As this is a conceptual learning day, I have removed all numbers and associated calculations. The focus of the lecture and discussion homework shifts to the acquisition of academic vocabulary and transforming the student theories into scientifically accurate concepts.

I give reasoning homework with the focus on application of the learned concepts to new phenomena. I made the homework of descriptive statements and questions; each requires an in-depth response. Not all require a one-paragraph response following the modeled academic paragraph style from class. In some questions, I require students construct graphs, group terms, or label parts of a diagram.

<div style="background-color: #8B4513; color: white; text-align: center; padding: 20px;"> <h2 style="margin: 0;">GAS LAWS HOMEWORK</h2> </div>	<h3 style="margin: 0;">Homework</h3> <ul style="list-style-type: none"> □ Explain 2 situations and four graphs with the gas laws learned today. □ Key Terms – Include these in your explanations. <ul style="list-style-type: none"> □ Pressure, Temperature, Volume, moles □ Variables, Constants □ Directly Proportional □ Inversely proportional
<h3 style="margin: 0;">For each of the following graphs</h3> <ul style="list-style-type: none"> □ Explain what each is showing/exemplifying. □ Tell the variables and the constants. □ Tell how the variables are related. □ Give real life examples where this law is applicable. □ Responses should be around 1 paragraph. 	<h3 style="margin: 0;">Relating Variables</h3> <ul style="list-style-type: none"> □ In the Northern plain states, car owners have to add air to their tires in the winter. Explain this practice using the gas laws. Specify variables and back up your answers.

Figure 16. Conceptual writing homework presented to students after the first day of gas laws instruction.

In the homework problem set shown above, I asked students to perform a couple of writing tasks. Students needed to use their prior knowledge to explain phenomena that may or may not be new to them. Then, students were asked to label graphs based on the applicable gas law and give an example of when and how this law is applied in real-life situations.

Wednesday, 100-minute block period.

This day in the weeklong progression is quantitative, or calculation based. The period is structured with a focused on quantifying the theories and concepts learned through writing and discussion on Monday. The basic lesson plan for a Wednesday follows below.

Wednesday Lesson Plan Template

Day: M T **W** Th F **Date:** / / **Title:**

Purpose:

Objectives/Standards:

- TSWBAT

-

-

Schedule:

Time	Activity/Description	Materials	Prep
10	Conceptual discussion (CD) – read – discuss – report using the CHW. Collect.	Lab	Focus ques.
55	Lab – Name of Lab,		Copy
20	Lecture (L) – cover calculations for the week. Work and go over sample problems		Ppt
15	Homework (HW) question prep <ul style="list-style-type: none"> - Assigned problems - Explanation Prep (PSA) - expectations 		Copy Post

Discipline:

Period & Student	Issue	Result

Reflection:

Notes	Changes

Conceptual writing discussion.

The class starts with discussion of the homework. Students pass and read the explanations of their group members. They may write comments on the papers they read with either statements of support or questions to the reasoning applied in the writing. Following the reading of group mates' work, groups engage in conversation to come to consensus regarding the reasoning or respond to a focus given for the discussion. At the end of the conversation, about 5 minutes, groups write a one-sentence blurb of understanding or question. Groups then report out to the class.

Following the discussion, students perform a lab or activity appropriate to the concept learned. The lab incorporates both application of concepts and introduces calculations used in conjunction with the theory. Although students have yet to receive formal training on the calculation processes, they will have one week to finish the calculations, during which they will learn the calculations.

Calculations are the necessary, quantitative aspect of chemical theory. The lecture following the lab gives students formal instruction regarding the use of numbers and formulas to quantify observations. The lecture proceeds for 15 to 20 minutes. I then give students homework problems for reinforcement.

Problem solving analysis.

Homework problems are accompanied with a writing component. The problem solving analysis component of the homework is an important learning tool and formative assessment. The analysis of the thought process and rationale for problem solving procedure is a high order thinking and learning method (Rivard, 1994). Students use the following template to guide their analysis of their problem solving method. Students complete the problem solving analysis on the same sheet as their homework, either at the end of the homework or as they perform the problem.

Problem Solving Analysis Template and Model

What I Did	Why I did That
$\frac{25.8\text{g Hg}}{\text{X atoms Hg}} =$ <p>In this step I did ... Say what you did. For each of the next steps explain what you added or how you got to that step from the previous step.</p>	<p>- For every box on this side you are going to give the rationale for the corresponding step on the other side.</p> <p>- Think of it like a proof in geometry. Everything you do has a reason. Think about the reason, then write it on this side.</p>
$\frac{25.8\text{g Hg}}{\text{X atoms Hg}} = \frac{\text{g Hg}}{\text{atoms Hg}}$ <p>Then I did this...you will explain this.</p>	<p>- The more detail / the better the reason you give, the better you will understand what you are doing.</p>
$\frac{25.8\text{g Hg}}{\text{X atoms Hg}} = \frac{200.59 \text{ g Hg}}{6.02 \times 10^{23} \text{ atoms Hg}}$ <p>Then I put this number here. I got it from here.</p> <p>$X = 7.74 \times 10^{22} \text{ atoms Hg}$</p>	
Did I Get the Correct Answer?	How do I know?
<p>Do you think you have reached the correct answer?</p>	<p>Referring to the above process you used, what things are you certain are correct.</p>

Students use the above template, with a worked example, for creating this writing piece. Students tell what they did, why they did it and then self-assess their problem solving method and answer. This writing is less formal in structure and language. Students use their own words and may use bullet points

as opposed to paragraph formatting. Homework problems and explanation are due at the beginning of the Friday class.

Friday, 100-minute block period.

I focus the final day of the week on the combination of qualitative theory and quantitative problem solving. Monday, students develop conceptual understanding in chemistry through explanation of observed phenomena. Wednesday, students learn the calculation procedures and formulas associated with the concepts. Friday, students combine quantitative and qualitative together to see the big picture, relate concepts to the problems, and associate problems with the concepts. I have built time into the day to help with lab calculations and writing as well as time to work through extra problems.

Friday Lesson Plan Template

Day: M T W Th **F** **Date:** / / **Title:**

Purpose:

Objectives/Standards:

- TSWBAT

- -

Schedule:

Time	Activity/Description	Materials	Prep
10	Conceptual Writing (CW) - prompt	Lab	Ppt
10	Concept discussion (CD)		
20	Homework Help (HWH) – collect when done.		
15	Help with lab calculations, relate to HW.		
25	Lecture (L) – Connecting concepts and calcs.		Ppt
10	Homework quiz (HWQ) prep		Copy Post

Discipline:

Period & Student	Issue	Result

Reflection:

Notes	Changes

Conceptual writing activity.

To incorporate both concepts and calculations, Friday starts with concept writing. I give students a writing prompt on the projector. With their notes and group members, students respond to the prompt with a one-paragraph writing. I remind students to adhere to the academic writing model and they begin the paragraph with the conclusion and then state all evidence pointing to the conclusion. This precedes the discussion.

Concept Discussion.

Following the writings, students engage in a brief table discussion, followed by a class discussion. Each group summarizes the thoughts of the group members to report to the class. Explanations are related to the conceptual writing performed during the Monday class and follow the same model as the Monday concept discussion.

The remainder of the day is a weekly review. Students get help with their questions regarding the homework and the lab. Students can ask questions from the previous night homework and I can work them out. After this process, students turn the homework in for grading.

The schedule for Friday is flexible. The teacher may give additional instruction to supplement learning, get students who have missed class back up

to speed, go over more examples, or ask more questions to help conceptual understanding. In the event of a shortened week, a teacher may cover new material.

References

- Anderson, L., & National Society for the Study of Education. (1994). *Bloom's taxonomy :A forty-year retrospective*. Chicago: NSSE ;Distributed by the University of Chicago Press.
- Bernstein, B. (2004). Social class and pedagogic practice. *The Routledge Falmerreader in sociology of education*. Ball, S.J. (Eds). London: Routledge Falmer. 196-217.
- Bransford, J., Brown, A., & Cocking, R. (Eds.). (2000). How people learn: Brain, mind, experience, and school: expanded edition (2nd ed.). National Academy Press: Washington, D.C.
- Bowers, J. (2007). *Chemistry: Matter and change* (California Edition.). Glencoe/McGraw-Hill.
- Brown, B. A., & Ryoo, K. (2008). Teaching science as a language: A "content-first" approach to science teaching. *Journal of Research in Science Teaching*, 45(5), 529-553.
- Common Core State Standards Initiative. (2010). Common core state standards: For English language arts and literacy in history/social studies, science, and technical subjects. Retrieved August 19, 2011 from http://www.corestandards.org/assets/CCSSI_ELA%20Standards.pdf
- Curriculum Development and Supplemental Materials Commission. (2000). *Science framework for California public schools: Kindergarten through grade twelve*. Sacramento, CA: California Department of Education. Retrieved August 19, 2011 from <http://www.cde.ca.gov/be/st/ss/documents/sciencetnd.pdf>
- Deci, E. L. (1995). Why we do what we do: The dynamics of personal autonomy. New York: Putnam's Sons.
- Gersten, R., Keating, T., & Becker, W. C. (1988). The continued impact of the direct instruction model: Longitudinal studies of follow through students. *Education and Treatment of Children*, 11(4), 318-327.

- Kuhn, T. S. (1996). *The structure of scientific revolutions (3rd ed.)*. Chicago: University of Chicago Press.
- Langer, J. A. (1986). Learning through writing: Study skills in the content areas. *Journal of Reading*, 29, 400-406.
- Langer, J. A., & Applebee, A. N. (1986). Reading and writing instruction: Toward a theory of teaching and learning. *Review of Research in Education*, 13(1), 171 -194.
- Levy, F., & Murnane, R. J. (2004). *The new division of labor: How computers are creating the next job market*. Princeton, New Jersey: Princeton University Press.
- Malachowski, M. (1988). The use of journals to enhance chemical understanding in a liberal-arts chemistry class. *Journal of Chemical Education*, 65, 439-440.
- Marzano, R. (1991). Fostering thinking across the curriculum through knowledge restructuring. *Journal of Reading*, 34, 518-525.
- McGuinn, P. (2006). No Child Left Behind and the transformation of federal education policy, 1965-2005. Lawrence, KS.: University Press of Kansas.
- National Center for Educational Statistics. (2005). *The nation's report card. Science 2005: National Assessment of Educational Progress at grade 8.* . Washington, DC: Institute of Education Sciences, U.S. Department of Education. Retrieved August 19, 2011 from http://nationsreportcard.gov/science_2005/s0106.asp
- National Center for Education Statistics. (2009). *The nation's report card. Science 2009: National Assessment of Educational Progress at grade 12.* Washington, DC: Institute of Education Sciences, U.S. Department of Education. Retrieved August 19, 2011 from http://nationsreportcard.gov/science_2009/g12_nat.asp
- National Commission on Excellence in Education. (1983). Archived: A Nation At Risk. Evaluative Reports; Policy Guidance, Retrieved November 8, 2010, from <http://www2.ed.gov/pubs/NatAtRisk/risk.html>
- Nersessian, N. J. (1999). Model-based reasoning in conceptual change. In L. Magnani, N. J. Nersessian, & P. Thagard (Eds.). *Model-Based Reasoning in*

Scientific Discovery (pp. 5-22). New York: Kluwer Academic/Plenum Publishers.

Organization for Economic Co-operation and Development. (2007). *PISA 2006: science competencies for tomorrow's world*. Paris: OECD.

Palincsar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. *Cognition and Instruction*, 1(2), 117-175.

Pugalee, D. (2001). Writing, mathematics, and metacognition: Looking for connections through students' work in mathematical problem solving. *School Science and Mathematics*, 101, 236-245.

Rivard, L. (1994). A review of writing to learn in science: Implications for practice and research. *Journal of Research in Science Teaching*, 31, 969-983.

Rivard, L. (2004). Are language-based activities in science effective for all students, including low achievers? *Science Education*, 88(3), 420-42.

Robitaille, D. F. (1993). *Curriculum frameworks for mathematics and science: TIMSS Monograph No. 1*. University of British Columbia, Vancouver, British Columbia, Canada: Pacific Educational Press.

Smith, J. P., diSessa, A. A., & Roschelle, J. (1993). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *Journal of the Learning Sciences*, 3(2).

Schneps, M., Crouse, L., Harvard University, Smithsonian Institution, & Project STAR. (2002). *A private universe: Misconceptions that block learning*. S. Burlington, Vermont: Annenberg/CPB.

Strike, K., & Posner, G. (1982). Conceptual change and science teaching. *International Journal of Science Education*, 4(3), 231-240.

Taber, K. (2009). Progressing science education constructing the scientific research programme into the contingent nature of learning science. Dordrecht, Netherlands: Springer.

- U.S. Department of Education. (2009). Digest of education statistics, 2009. Retrieved November 15, 2010, from http://nces.ed.gov/programs/digest/d09/tables/dt09_271.asp?referrer=report
- Vygotsky, L. S. (1986). *Thought and language*. Cambridge, MA: MIT Press.
- Wells, G. (2007) Semiotic mediation, dialogue, and the construction of knowledge. *Human Development*, 50, 244-274.
- Wink, J., L. Putney (2002). *A vision of Vygotsky*. Boston: Allyn and Bacon.
- Yamauchi, L. (2005). Culture matters: Research and development of culturally relevant instruction. In C.R. O'Donnell & L. A. Yamauchi (Eds.), *Culture & context in human behavior change* (pp. 103-124). New York: Peter Lang Publishing Group.
- Zemelman, S., Daniels, H., & Hyde, A. (2005). *Best practice: Today's standards for teaching and learning in America's schools* (3rd ed.). Portsmouth, New Hampshire: Heinemann.