

Impact of STS (Context-Based Type of Teaching) in Comparison With a  
Textbook Approach on Attitudes and Achievement in  
Community College Chemistry Classrooms

by  
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## ABSTRACT

The purpose of this study was to analyze the impact of a context-based teaching approach (STS) versus a more traditional textbook approach on the attitudes and achievement of community college chemistry students. In studying attitudes toward chemistry within this study, I used a 30-item Likert scale in order to study the importance of chemistry in students' lives, the importance of chemistry, the difficulty of chemistry, interest in chemistry, and the usefulness of chemistry for their future career. Though the STS approach students had higher attitude post scores, there was no significant difference between the STS and textbook students' attitude post scores. It was noted that females had higher postattitude scores in the STS group, while males had higher postattitude scores in the textbook group. With regard to postachievement, I noted that males had higher scores in both groups. A correlation existed between postattitude and postachievement in the STS classroom. In summary, while an association between attitude and achievement was found in the STS classroom, teaching approach or sex was not found to influence attitudes, while sex was also not found to influence achievement. These results, overall, suggest that attitudes are not expected to change on the basis of either teaching approach or gender, and that techniques other than changing the teaching approach would need to be used in order to improve the attitudes of students. Qualitative analysis of an online discussion activity on Energy revealed that STS students were able to apply aspects of chemistry in decision making related to socioscientific issues. Additional analysis of interview and written responses provided insight regarding attitudes toward

chemistry, with respect to topics of applicability of chemistry to life, difficulties with chemistry, teaching approach for chemistry, and the intent for enrolling in additional chemistry courses. In addition, the surveys of female students brought out subcategories with regard to emotional and professional characteristics of a good teacher, under the category of characteristics of teaching approach. With respect to the category of course experience, subcategories of useful knowledge to solve real-life problems and knowledge for future career were revealed. The differences between the control group females and STS group females with respect to these characteristics was striking and threw insight into how teacher behavior and teaching approach shape student attitudes to chemistry in case of female students.

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## CHAPTER 1

### INTRODUCTION

The main purpose of the proposed PhD study was to gauge the impact of a context-based teaching approach (science-technology-society STS) vs. textbook type of teaching on attitudes and achievement in community college chemistry classrooms. A total of 75 students ( $N = 75$ ) participated, 35 belonging to the textbook group and 40 to the context-based group. Data was collected from two parallel sections of fundamental chemistry in fall 2009 and two parallel sections in spring 2010. This study employed a Research Design where two techniques were used to test for achievement differences between a control (textbook) and test (context-based) group: One, the average normalized gain of one group over the other. The second, an ANOVA to test mean differences between the control and test group.

Attitudes toward chemistry were gauged before and after teaching using a Likert scale. Five students were subject to structured interviews. Two students with a low normalized gain average in attitudes, and three with a medium normalized gain average gave consent from the experimental group. Structured interviews of the students led to the construction of models for the students using qualitative analysis. Their achievement scores and their responses to aspects of the teaching they found useful were examined. This was done to get an insight into what it was about the type of teaching that was/not useful to them, and their future choices of subjects in science.

In addition to exploring attitudinal and achievement differences across gender in each of the two groups, the correlations between attitude and achievement were examined.

### **Research Questions**

- RQ1: Does a context-based teaching approach improve students' attitudes toward fundamental chemistry in comparison to a textbook-based teaching approach in community college classrooms?
- RQ2: Does context-based teaching affect student achievement in fundamental chemistry in comparison to a textbook-based teaching approach?
- RQ3: While controlling for variances in preintervention student achievement scores in a chemistry course, does sex (male, female) affect student achievement scores where a textbook-based teaching strategy is employed?
- RQ4: While controlling for variances in preintervention student achievement scores in a chemistry course, does sex (male, female) affect student achievement scores where a context-based teaching strategy is employed?
- RQ 5: While controlling for preintervention variances in student attitudes toward chemistry, does sex (male, female) affect student

attitudes toward chemistry in a fundamental chemistry course  
where a textbook-based teaching strategy is used?

RQ 6: While controlling for variances in preintervention student  
attitudes toward chemistry, does sex (male, female) affect student  
attitudes toward chemistry in a fundamental chemistry course  
where a context-based teaching strategy is used?

RQ 7a: Is there a correlation between attitude and achievement in the  
textbook classroom?

RQ 7b: Is there a correlation between attitude and achievement in the  
context-based classroom?

RQ 8a: What aspects of the type of teaching were/not useful for students?

RQ 8b: What are the future science course choices of students?

### **Rationale**

The community college located in inner city of Phoenix has 50% of students taking remedial math and over 60% of students taking remedial reading courses. A pilot study conducted by the researcher in spring and summer of 2008 presented an alarming picture of the attitudes toward chemistry among the community college students. The existence of negative attitudes toward chemistry (with respect to future course enrollment in chemistry and career aspirations) and the importance of context are discussed in detail in the following literature review section.

Attitudes toward science currently constitute a very important issue. Research has found that less than 1.2% of high school graduates are interested in scientific careers (Leyden, 1984): this has become a worldwide problem, and changes within the classroom must take place in order to improve the current situation. More positive student attitudes could be an important factor in increasing science course enrollment as well as improving achievement in the area of science (Simpson & Oliver, 1985). Additionally, improving attitudes toward science should serve the purpose of generating greater interest in scientific careers.

The learning environment and student involvement in learning has an important influence upon student attitudes toward science (Haladyna & Shaughnessy, 1982). Specifically, the STS approach focuses upon student questions and interests (Yager, 1996), and may serve to improve the attitudes of students toward science. Additionally, creativity is integral to science and the scientific process (Hodson & Reid, 1988), and it serves to improve motivation, curiosity, and can help improve achievement scores (Torrance, 1981). Penick (1996) notes that using provocative questions, an important component of the STS approach, can help improve students' creativity. This suggests the importance of the STS approach in improving achievement scores. Additionally, effective science instruction could potentially improve attitudes toward science, and students with more positive attitudes would be more likely to regularly attend class, read assignments, and complete homework (Abell & Lederman, 2007).

## CHAPTER 2

### LITERATURE REVIEW

Both the American Association for the Advancement of Science (1990) and the National Research Council (1996) have emphasized the importance of educating people to live in our increasingly science- and technology-rich society, as well as the need to train the next generation of scientists. An increasingly recognized need is that of teaching non-science majors the skills of *functional scientific literacy* (Laugksch, 2000; Shamos, 1995) –knowledge of the scientific vocabulary and skills for conversing, reading, and writing coherently about science in a non-technical context – as essential components of conscientious citizenship (Tro, 2004). While many educational institutions require students to take one or several courses in science as part of their general education curriculum, it is not clear whether such courses actually change students' attitudes toward science (Walczak & Walczak, 2009). Of particular challenge is making chemistry interesting and engaging to non-science majors.

#### **The Community College Learner**

The community college learner will be reviewed in this section as it is the context of this study. In 1999–2000, 42% of all undergraduates were enrolled at public 2-year institutions, commonly known as community colleges (Horn, Peter, & Rooney, 2002). Many community college students face barriers to entry such as poor academic performance in high school, limited English-language skills or other basic skill deficiencies (Grubb, 1999). About 60% of the students entering

an inner city community college in Arizona end up taking developmental courses in reading and math.

A significant number of students who enter community colleges choose an informal credential and do not complete a formal credential (Berkner, Horn, & Clune, 2000), while only one out of four community college transfers had received a bachelor's degree by 1994 (Laanan, 2001). And even when this happens, there is the first-term decline in grade point average (Cohen & Brawer, 2002). The reasons for this happening are not fully understood.

Interesting perceptions exist regarding both non-science majors taking physical science courses, and physical science courses themselves. Professors perceive these students to have relatively weak backgrounds in science and math (Duchovic, Maloney, Majumdar, & Manalis, 1998), to have little interest in learning science (Beiswenger, Stepan, & McClurg, 1998), to be unmotivated, to have relatively poor study habits, and to have relatively poor achievement.

When most science majors come to college, they are eager to learn and intend doing well. However, in the community college, doing well occurs with only a small portion of freshman taking science. According to Education theorist Sheila Tobias, "college science students can be divided two different groups: those who climb the rungs of the curriculum ladder and eventually earn a science degree, and those who have the ambition and ability to succeed, but along the way, lose motivation and interest in science courses and switch to nonscience



fields” (citing Tobias, in Lord, 2008). To address this, the present study proposes a change in the way the fundamental chemistry course is taught.

Lord (2008) identifies several problems in the way college science courses are taught that prevent students from continuing in the major. These include (1) no relevance of science to students' lives and personal interests, (2) the students learn passively in the classroom, (3) an emphasis on competing for grades rather than cooperative learning, and (4) a focus on algorithmic problem solving in the form of a string of formulas as opposed to conceptual understanding.

### **The Importance of Attitudes Toward Science**

‘Attitude’ has been used interchangeably with terms such as value, belief, and opinion. Abell and Lederman (2007) cite Petty and Cacioppo, who make a distinction between attitudes toward science and scientific attitudes by describing attitude as a general and enduring positive or negative feeling that one may have about some person, object, or issue. It is important to note that the definitions of the words ‘feeling’ and ‘emotion’ used in attitude research are not clear.

Flávia, Teixeira dos Santos, and Fleury (2003) clarified this, designating the word ‘*feeling*’ to characterize the mental experience of an emotion, and the word ‘*emotion*’ to describe organic reactions that prompt the feeling. ‘*Feeling*’ therefore is a dimension of the concept of attitude, with both *feeling* and *emotion* considered essential aspects of the affective dimension of learning science (Flávia, Teixeira dos Santos, & Fleury, 2003). Emotions are further classified into *primary* (universal and automated) and *secondary*, subtle variations of the

primary and tuned by experience Flávia, Teixeira, dos Santos, & Fleury, 2003).

They are at the heart of attitudes that students develop throughout science.

As early as 1958, attitude has been found to represent the emotional orientation of a student toward the topic at hand (Freedman, 1997). For Jensen (2000, citing LeDoux, 1996), emotions are important to all mental functions, contributing significantly to attention, perception, memory and problem solving, without which there is a failure to attend to details. Jensen (2000) emphasizes the importance of emotions in learning as this helps us to focus our reason and logic, what is referred to as '*emotional logic*'. In the chemistry classroom, while the student's logical side may help set a goal nonetheless it is his/her emotions that provide the passion to persevere in learning, i.e. the emotions behind the goals provide the energy to accomplish them.

Abell and Lederman (2007) cite Gardner (1975) to differentiate between 'attitudes towards science' and 'scientific attitudes.' The latter is a complex mixture of the yearning to know and understand; a search for data and making sense of the data, a demand for verification, and a consideration of consequences (Abell & Lederman, 2007). 'Scientific attitudes' have a predominant cognitive orientation, whereas 'attitude toward science' is predominantly affective.

Over the last three decades, a substantial body of research has accumulated on the importance of various attitudes toward science and the relationship between these attitudes and science achievement. Stedman (1997), as cited in Papanastasiou and Zembylas, 2002 posits that this is a result of "a Cold

War relic when being first to the moon and the world's leading super power preoccupied Washington policymakers" (p. 5) and for which the USA is "fixated" on math and science achievement. The extensive literature covers national studies and international comparisons using numerous research methods. It is however of interest to note that there have not been uniform answers about the magnitude and direction of the attitude-achievement relationship, with varying comparisons across countries, depending on their cultures, social systems, and schools (Wang & Staver 1996).

Studies in science education (Papanastasiou & Zembylas, 2004; Cukrowska, Staskun, & Schoeman, 1999; Tuan & Shieh, 2005; Rennie & Punch, 1991) have explored the relationship between student attitudes toward science and achievement. Conflicting correlations between academic achievement in Science and attitudes have been reported.

Several studies found that science attitudes were positively correlated with science achievement and participation in advanced science courses (Lee & Burkam, 1996; Simpson & Oliver, 1990). The initial research in this area was influenced by Bloom's (1976) theory of school learning (cited in Papanastasiou & Zembylas, 2002) in which he suggested that 25 percent of the variance in school achievement could be attributed to students' attitudes toward the subject, as well as to their school environment, and their self-belief (Papanastasiou & Zembylas, 2002, p. 470). However, Bloom's prediction has been mostly in contrast to the research findings in the subject of science, which usually reports common

variance of less than 5 per cent (Rennie & Punch, 1991, cited by Papanastasiou & Zembylas, 2002).

Over the last three decades, various research studies (House, 1996; Lee & Burkam, 1996) identified various aspects of the attitude-achievement relationship, but “failed to explain the surprisingly low association found between attitude and achievement (Papanastasiou & Zembylas, 2002, p. 471).” It is possible that much of the confusion and inconclusiveness of the research in this area can be attributed to the lack of a theoretical framework to direct the investigations and uncertainty about its direction (Rennie & Punch, 1991). Furthermore, other researchers posit that the weak association between attitudes and achievement might also be related to the perceived difficulty of science, the lack of effective teaching and the influence of ethnic and home background (Osborne, Driver, & Simon, 1998).

Cukrowska, Staskun, and Schoeman (1999) found a positive relationship between attitudes and academic achievement in first year chemistry, which found subsequent support in Tuan, Chin, & Shieh’s study (2005) finding a correlation between achievement and both attitude and motivation toward learning science among junior high school students. These however run counter to Rennie and Punch’s (1991) earlier study on a borderline significant correlation between subsequent achievement and attitudes towards science among 8<sup>th</sup> grade students, leading them to conclude that students’ past performance is a primary predictor of subsequent achievement.

Attitude toward science is related to achievement in science knowledge. Low positive correlations between attitude toward science and achievement in science have been reported (Keeves & Morganstern, 1992). Liking science was correlated with achievement in science. Whether there is a correlation between the two in a community college classroom is a question that remains to be seen. Scantlebury and Baker (2007) report that girls tend to have less favorable attitudes toward science than boys. Girls' science-related interests are more focused on the biological than physical sciences (Jones, Howe, & Rua, 2000). Furthermore, boys and girls appear to view science as a male-dominated school subject and consider science to be a male profession (Jones, Howe, & Rua, 2000). This is largely due to different cultural expectations placed on girls and boys by parents, teachers, and peers (Jones, Howe, & Rua, 2000).

A review of available literature would thus reveal the inconsistency among reported studies. Whether there exists a correlation between the two, and if there are any interactions across gender in a community college classroom is a question that remains to be seen. Also concerns about the conduct of attitude research studies are largely about the instruments used to measure student attitudes (Dulski, Dulski, & Raven, 1995). While some instruments are designed to measure scientific attitudes, others seek to identify attitudes towards science.

Attitudes toward science classes and toward science teachers degrade over time (Mbajorgu & Ali, 2003). The more students study science in school, the more their attitudes decline. A study by Ramsden (1998) yielded the following:

1. Science is considered to be difficult and not relevant to the lives of most people;
2. Science is supposed to cause social and environmental problems;
3. Science is more attractive to males than females;
4. The interest in science decreases over the years of secondary schooling;
5. The more negative views are associated with the physical sciences rather than biological
6. Piburn and Baker (1993) illustrate that not just one, but a wide gamut of components are included in measures of attitudes toward science such as (a) the perception of the science teacher; (b) the anxiety toward science; (c) the motivation towards science; (d) the enjoyment of science; and (e) the nature of the classroom environment.
7. Research has found that a dislike of science develops among students during middle school years (Morrell & Lederman, 1998). Current science education at schools results in lack of interest among students who study science. Leyden (1984) states that less than 1.2% of high school graduates are interested in scientific careers. The decline in students' interests in taking up scientific careers is a worldwide

problem. To overcome this problem and to accomplish the major goals of science education emphasized by contemporary science education reform (American Association for the Advancement of Science, 2000; National Research Council, 1996) in the classrooms, a shift is necessary from what has traditionally been experienced. The use of the STS approach may help to create this shift.

### **Challenges in Chemical Education**

Aikenhead (2005) documented three major failures of the traditional science curriculum: (a) chronic decline in student enrolment due to students' disenchantment in school science, particularly for young women and students marginalized on the basis of their culture; (b) the dishonest and mythical images about science and scientists that the curriculum conveys; and (c) most students tend not to learn science meaningfully.

Gilbert (2006) noted that the past 20 years of research in all parts of the world talk about the interrelated problems plaguing chemical education such as overload, isolated facts, lack of relevance, and lack of emphasis. Gilbert (2006) uses Schwartz's (2006) ladder metaphor to explain this phenomenon which was confirmed in my pilot study. Gilbert (2006) pointed out that it is therefore fruitful to begin with the notion of context as a basis for curriculum design if one wishes to bring need-to-know chemistry closer to the life of the student.

Banya (2004) made the point that students have to see the relevance of science to their lives otherwise the course will have no meaning to them. I see

meaning as a powerful principle of learning. In the pilot study, the dislike expressed by students for chemistry was alarming. The lack of relevance in chemical education calls for the revival of the 1980-1990 science-technology-society STS movement (see section on STS Movement).

### **Attitudes Toward Chemistry, and Instruments Used to Gauge Attitude**

In the 1980s, a Brazilian pop group made the song called I hate chemistry. This captured the general feeling from adolescents toward chemistry. Banya (2004, p. 14) mentions that it is common to hear from students in the corridors of high school buildings statements such as: “I cannot understand chemistry. Why should I learn chemistry anyway? I don’t know of anyone who is successful because of studying chemistry.”

One of the most recent studies of attitudes toward chemistry investigated factors associated with changes in attitude toward learning chemistry (Berg 2005). Sixty-six first-year university chemistry students took a pre- and postcourse attitude questionnaire. Six students with the largest attitude changes (both positive and negative) were interviewed. A positive attitude change was associated with evidence of motivated behavior.

For a 2004 study on attitudes toward chemistry, Banya (2004) designed a Chemistry Attitude Influencing Factors (CAIF) instrument. It was modeled on the Chemistry Attitude and Experience Questionnaire (CAEQ) designed and tested by Dalgety, Coll, & Jones (2003). Banya (2004) administered the survey questionnaire to 183 young high school female students across the U.S. The



survey was followed by a semi-structured interview in which questions were adopted from the CAIF instrument involving three young female students. Banya (2004) reported that self-confidence toward chemistry, the influence of role models, and knowledge about the usefulness of chemistry affect the decision of young female students about the study of chemistry.

Dalgety, Coll, & Jones (2003) undertook the development of the CAEQ to measure first-year university chemistry students' attitudes toward chemistry. Dalgety, Coll, & Jones (2003) claimed construct validity of the instrument. It was piloted with a cohort of 129 science and technology students at the end of their first year. The modified instrument was subsequently administered on two occasions at two tertiary institutions.

CAEQ developed by Dalgety, Coll, and Jones (2003) had an average reliability for the instrument of 0.74 at the start of the year ( $n = 332$ ) and 0.84 at the end of the semester ( $n = 337$ ). Also the CAEQ had items for students who are university students: The chemistry tutors have made me feel I have the ability to continue in science; It was easy to find a tutor to discuss a problem with; The tutors explained problems clearly to me; The demonstrators explained problems clearly to me. Community college students do not have chemistry tutors/demonstrators. This made me think that some of the items on this scale may not be suitable to my students.

Dalgety, Coll, & Jones (2003) evaluated convergent and discriminant validity by factor, reliability, and statistical discriminant validity analysis, and all

subscales gave statistically significant differences between students who were and students who were not planning to take chemistry in their second year, which confirms concurrent validity. The fact that the learning experience subscales had significant correlations with all attitude toward chemistry and chemistry self-efficacy subscales indicates that this instrument also possesses high predictive validity.

Salta and Tzougraki (2004) undertook the development of a valid and reliable instrument for measurement of attitude toward chemistry using 576 11th grade Greek students. Interest, the usefulness of chemistry course, difficulty, and the importance of chemistry were investigated. Sex and study specialization differences in students' attitudes toward chemistry were also examined. Grades for the chemistry course were used to measure students' achievement in chemistry and the correlation of achievement with students' attitudes toward chemistry was explored. This scale seemed suitable both in terms of grade 11 and items to my students.

In regard to sex, Salta and Tzougraki (2004) found no significant difference in the level of interest, usefulness, and importance attributed to chemistry. However, females had a significantly less positive attitude as compared with males in regard to the difficulty of chemistry courses. It was also found that students specializing in science-medicine had a significantly more positive attitude as compared with students specializing in other areas. Additionally, students specializing in humanities had significantly less positive

attitudes regarding the difficulty, interest, and usefulness attributed to chemistry as compared with students specializing in engineering studies. However, no significant difference was found in attitudes in regard to the importance of chemistry between students specializing in humanities and students specializing in engineering. Also, a low positive correlation was found between students' achievement in chemistry and their attitudes toward chemistry. The correlation between students' achievement and their perceived difficulty of chemistry was found to be stronger.

Henderleiter and Pringle (1999) developed a 24- statement Likert survey at the University of Northern Colorado. The Likert survey had items applicable to analytical chemistry majors. For example, Analytical chemists are very precise in their work; I could use skills learned in analytical chemistry in the career I'd like to pursue; Analytical chemistry is boring. They administered it to university control and experimental groups ( $N = 44$ ) to determine the effects of context-based laboratory experiments on attitudes of analytical chemistry students. Although their survey data did not suggest attitude changes, interviews and observational data did suggest changes. Student-student interactions were at greater depth and more prevalent in the experimental than in control classes. The authors say that this may indicate the experimental group's deeper level of involvement with the material, suggesting more positive attitudes of the experimental class.

The community college students' background requires items of moderate difficulty. Hence it was decided to choose the Likert scale developed by Salta and Tzougraki (2004). The scale consists of 30 items. In particular, it would investigate students' attitudes regarding:

- The importance of chemistry in their life
- The importance of chemistry course
- The difficulty of chemistry course
- The interest of chemistry course
- The usefulness of chemistry course for their future career.

### **The STS Movement**

Hurd is often credited for advocating science education for young people so that it would enhance their daily lives and enable them to recognize its value to themselves and society, utilizing the phrases “science for life and living” or “science enlightenment”, “science and technology in society” to get his message across (Totten & Pedersen, 2007). The “Science and Technology in Society” was a grass roots movement that began quietly in many parts of the country, and with no definite date as to its beginning (citing Spector in Totten & Pedersen, 2007). Hurd had seen the need for science education to examine the critical issues impacting society and the world, while Aikenhead called for teaching science by embedding it within two contexts: technological and social (Solomon & Aikenhead, 1994). Emergent by the 1970s, the embedding in contexts approach is

called STS in North America, while it is referred to as a 'context-based' approach in Europe (Bennett, Lubben, & Hogarth, 2007).

The STS movement gained popularity in the 1980s as a reform focusing on a science for all. Social issues formed the heart of STS. In the 1970s, 1980s, and 1990s, STS was a national priority in the U. K. There was also rapid growth of STS in Netherlands, Scandinavia, and Israel. The projects involved using science and technology to resolve social issues. Ziman (1994) advocated the use of STS in teaching science concepts using real-world contexts. Information and skills have to be rooted in a sociological basis in order for them to be considered worthy of being imparted to students (Ziman, 1994).

STS is a call for relevance. Instead of canonical abstract ideas most often decontextualized from student's everyday life, this perspective includes making students cognizant of the human and social dimensions of scientific practice and its consequences. Eight-five percent of students need citizenship preparation for dealing with real life, whereas only a smaller percentage requires preprofessional training for scientific careers (Abell & Lederman, 2007). Therefore, the need for knowledge about science and scientists far outweighs the need for knowledge of canonical science. Such an approach of teaching science provides a context of a relevant problem that students address with a variety of tools, including those that science offers (Abell & Lederman, 2007).

For Bingle and Gaskell (1994), STS aims to develop decision-making, whereas Fourez (1997) posits that problem-solving skills, autonomy and capacity

to communicate when dealing with specific situations are its main objectives.

Ziman (1994) identified different approaches to STS education: making “valid science” relevant, the vocational approach, the philosophical approach, the sociological approach, and the problematic approach. His thoughts on these approaches are enlightening:

There is no single best approach. There is not even an optimum recipe for combining the various aspects of the STS theme – mix six ounces of History with three tablespoons of undiluted Philosophy and a pinch of Sociology, season with Relevant Problems and bake for three periods a week in an Interdisciplinary oven at a moderate Ideological temperature. Teachers must make their own lists of ingredients, and learn to combine and cook them to suit the tastes and nutritional needs of those to whom the dish is to be served. (Ziman, 1994, p. 133)

Such interactive learning approaches are often identified as being essential to STS science instruction (Solomon, 1993). From reviewing the existing literature, research evidence suggests the following (Byrne & Johnstone, 1988).

1. In terms of learning science content, simulations and games can be just as effective as traditional methods. In terms of developing positive attitudes, simulations and games can be far more effective than traditional methods.
2. In terms of attitude development, the strategies of role playing, discussion and decision making can be highly effective.
3. Group discussion can stimulate thought and interest and develop greater commitment on the part of the students. (p. 45)
4. In terms of promoting an understanding of the processes of science, an analysis and evaluation of historical case studies can be effective.

Four common aims are thus embraced by STS approaches:

1. Increase citizen's scientific literacy;
2. Generate student interest in science and technology;
3. Encourage interest in the interactions among science, technology and society; and
4. Help students become better at critical thinking, logical reasoning, creative problem solving (Fourez, 1995), and especially decision making (Bingle & Gasket, 1994).

Such a humanistic perspective promoting practical utility and human values in the science curriculum is a challenge to the status quo of school science. Abell and Lederman (2007) note that at one extreme, there are policy-makers that value empirically tested approaches to evaluate what is best for students, while at the other extreme, policy-makers often ignore research in order to meet or sustain political realities. It should connect with societal events. In contrast, a traditional perspective is one that promotes professional science associations, the rigors of mental training, and academic screening to achieve exclusiveness and a scientist orientation.

### **The Impact of STS Teaching on Attitudes Toward Science**

Banerjee and Yager (1995) found that with STS instruction the attitudes toward science classes, the perceived usefulness of those classes, and science careers were much more positive than textbook classes. Yager and Tamir (1992) developed a unique in-service teacher model to disseminate the STS approach

called the Iowa Chautauqua Model. Blunck and Yager (1996) studied a total of 224 life science teachers from grades 4-12 in Iowa schools. In their study, these teachers developed STS modules utilizing the Iowa Chautauqua Model and taught the module for at least one month. Assessments were made before and after the STS experience. Analysis of the changes between pretest and posttest scores found that the use of STS resulted in positive achievement for the students of a majority of teachers. Improvement in a number of assessment domains was also found, which was in stark contrast to the decline in creativity skills and attitudes, the lack of change in proficiency with process skills, and the fact that students cannot apply process skills and concepts to new situations in most other classrooms.

In another study (Yager, Choi, Yager, & Akcay 2009), fifteen experienced grade 5-10 teachers each taught two sections of students, one using an STS approach, and one closely following the curriculum with a "directed inquiry" approach. This study also focused on the use of the Iowa Chautauqua Model. In this study, data was collected from five teaching and assessment domains, which consisted of science concepts, science process skills, creativity, attitudes, and applications of concepts and processes in new contexts. While the study did not find any significant difference in the concept domain between these two sections of students, students in the STS section had significantly higher scores in all other domain STS strategies were utilized for one class and traditional concept-organized strategies were utilized in another. Advantages of the STS program



included improving process skills, applying science concepts, increasing creativity, and improving attitude toward science. STS instruction was shown to have a significantly greater impact on students in positive attitudes towards science classes, towards the perceived usefulness of these classes, or toward science careers (Banerjee & Yager, 1995).

Yager and Yager (2006) found that middle school STS students applied science concepts in new situations better than students who studied science in a more traditional way. STS students also developed more positive attitudes about science (Mee-Kyeong, L. and I. Erdogan, 2007; Yager, Yager, & Lim, 2006).

From the literature reviewed, most studies have been carried out with middle schools and in science classes. In order to make conclusive statements about the role of STS instruction in student attitude change in chemistry, and student achievement in community college, it is critical to carry out actual investigations involving the impact of a STS (context-based) type of teaching in the community college classroom. Abell and Lederman (2007) reinforced an important point: the majority of students not pursuing an academic career are large (almost 85%), thus, the need for curriculum design to include this group because they have different needs. This is again an argument for a curriculum based on the STS approach.

Nachshon (2000) found that students in grades 10 and 11 who were taught a unit on Ionizing Radiation in the STS mode scored significantly higher than those who did not study the subjects in the STS mode. The students in the a study

by Nachshon and Lazarowitz (2002) reported that learning in the STS mode helped them to overcome their fears and prejudice against the subject. Students in STS science courses appeared to fair significantly better on achievement tests of canonical science than their counterparts in traditional courses (Mbajiorgu & Ali, 2003). However, there have been no studies conducted looking at the impact of a context-based approach on achievement in chemistry at the community college level.

The STS approach generates an environment where teaching and learning are built around student questions and interests. “STS focuses on personal needs of students and societal issues (ones often found in homes, schools and communities as well as the more global problems that should concern all humankind)” (Yager, 1996, p. 12).

### **STS Teaching and Creativity**

Hodson and Reid (1988) pointed out that creativity is integral to science as well as the scientific process. It is used in the many processes of science, including generating problems and hypothesis formation. Moreover, creativity improves motivation, curiosity, and can lead to higher achievement scores (Torrance, 1981). Many writers and researchers (Csikszentmihalyi, 1996; Penick, 1996; Richetti & Sheerin, 1999) conclude that question-posing and problem-finding are crucial, at the heart of originality, and form an extremely strong association with creativity.

Penick (1996) argues that creativity does not happen by chance and provides some practical suggestions for creating an environment where questions work best for improving student creativity. According to him, science teaching that uses provocative questions and creates a safe environment for exploring, risk-taking, experimentation, and speculation, can help improve students' creativity. Many studies indicate the importance of teachers, teaching strategies, learning environments, and parental influences on student attitudes toward science and creativity (Morrell & Lederman, 1998; Reynolds & Walberg, 1992; Shin, 2000).

Abell and Lederman (2007) say that effective science instruction has the potential to improve attitudes towards science. They point out that one should not ignore motivation to enroll in elective science courses and positive attitudes toward chemistry. They also indicated that students with more positive attitudes would attend class regularly, read assignments, and complete homework. Though attitudes tend to be relatively enduring within a person, they have the potential to change. Such authors emphasize the affective dimension of science learning as not merely a 'simple catalyst but a necessary condition for learning to occur' (Perrier & Nsengiyumva, 2003, p. 1124). They argue that affect surrounds cognition (Alsop & Watts, 2003) and that learning has to 'feel right' (Jensen, 2000).

Chemistry instructors have taken a number of approaches to motivate students to learn chemistry and to improve student attitudes towards chemistry (Walczak & Walczak, 2009, p. 985). Several approaches incorporate "real world"

components into course and laboratory experiences (Henderleiter & Pringle, 1999; Miller, Nakhleh, Nash, & Meyer, 2004; Hume, Carson, Hodgen, & Glaser, 2006), leading to a deeper level of student–student involvement, greater confidence about reasoning, greater metacognitive awareness, and better mastery of general concept knowledge than their counterparts in traditional courses and laboratories. Other authors report gains in adopting cooperative learning techniques (King, Hunter & Szczepura, 2002; Shibley & Zimmaro, 2002; Oliver-Hoyo & Allen, 2005). Students participating in cooperative learning activities had a stronger perception of the relevance of chemistry in their lives, greater enjoyment of chemistry, and had more positive attitudes toward learning chemistry than those participating in traditional courses (Walczak & Walczak, 2009).

### **Theoretical Framework: Learning Theory of Constructivism**

Researchers (Zimmerman & Schunk, 2003) have argued that a constructivist view of learning by acquisition involving active knowledge construction, evoking background knowledge, drawing from their personal experiences, using hands-on inquiry or group discussion that promotes the process of knowledge construction in learners, is highly valuable. Among its advantages is developing a sense of independence and autonomy and making students responsible for their own mistakes and results. The STS curriculum offers the benefits of all of these aspects of constructivism. Learning is an interpretive process in which each student has to come to an interpretation of what another

student said in a dialogue. This involves negotiation and interpretation when engaging in discourse that facilitates the action of negotiation and interpretation (Cobern, 1993).

The Constructivist Learning Model (CLM) will be utilized in the present study mainly due to its practical application, viewing learning as the active process of constructing a conceptual framework. We learn by making sense of our experiences of reality (Cobern, 1993). In particular, STS gives students the opportunity to take their daily phrases and meanings (the life-world) of chemical concepts and add an additional kind of knowledge - the scientific. Such a “two domain approach” to constructivism enables scientific knowledge to be learned in the context of their everyday lives (Solomon & Aikenhead, 1994).

## CHAPTER 3

### METHODS AND PROCEDURES

I designed the study to contrast two different chemistry teaching approaches, namely, context-based (STS) and textbook-oriented approaches on measures of student learning outcomes, i.e., attitudes toward chemistry and achievement. The IRB approval is attached as Appendix A. The Attitude instrument was borrowed from Salta and Tzougraki, 2004, and is attached as Appendix B. The achievement test gauged student understanding of concepts covered by the Maricopa Community College District competencies. Two parallel classes in fall 2009 were randomly designated as experimental and control sections, and two in the same way in spring 2010. Two possible independent (predictor) variables include the teaching approach and sex, and the dependent variables are the learning outcomes, namely, attitudes and achievement.

I have included in this chapter the instructional strategies I utilized in the two treatments, procedures I utilized for data collection, and the statistical techniques chosen for data analysis.

STS teaching involves making chemistry classes more exciting and meaningful for all students. The teaching and assessment strategies focus on the relationship between science, technology, and society (STS). STS incorporates a two-domain approach, with the two systems of knowing being the life-world and the scientific. That is, students have to learn scientific knowledge in the context of people's everyday lives. They move between phrases and meanings of the more

familiar everyday set of ideas and accept an additional kind of knowledge in their chemistry lessons.

To maximize my effectiveness in STS teaching, I familiarized myself with STS philosophy, the constructivist learning model, and STS teaching strategies. The student participants were enrolled in a community college. The treatment group students received the STS approach, while the control group a textbook approach. In the textbook approach, Zumdahl (2009) and Corwin (2009) books were followed closely for 10 weeks during the semester to ensure that a difference in teaching approach would be the only instructional variable. I have included a comparison of sample content outlines characteristic of the two formats as Appendix E. It shows congruence of unit topics. This allows identical assessment of all student participants. The time frame will also be the same for each group.

### **Target Population**

Convenience sampling was used to select participants for this study. This sampling method enabled the researcher to act within a certain time period and under conditions that facilitate data collection. By its nature, convenience sampling sacrifices generalizability and therefore may not provide sufficient representation of the target population. This means that those selected for the study may not necessarily represent the population being investigated. As such, replication may be necessary to fully validate study results (Keppel & Zedeck, 2001).

Keeping feasibility and the timeline of fall 2009-spring 2010 in mind, the proposed study involved 75 participants 35 of which were subject to textbook type of teaching and 40 to the context-based type of teaching.

### **Variables**

There are four unique variables in the study used to answer the research questions. The variables include Type of Teaching, Sex, Student Achievement Scores, and Student Attitudes. Type of Teaching was operationalized as the context group and the textbook group, while sex was operationalized as male and female.

### **Independent Variables**

The Independent variables for this study are Type of Training and Sex. Type of training is composed of two groups, Context Based Training and Text Booked Training. This variable is used in Research Questions 1 and 2:

1. Does a context-based teaching approach improve students' attitudes toward fundamental chemistry in comparison to a textbook-based teaching approach in community college classrooms?
2. Does context-based teaching affect student achievement in fundamental chemistry in comparison to a textbook-based teaching approach?

Sex, the second independent variable is defined at two levels, male and female. This variable is an Ex Post Facto variable in that the condition male-ness and female-ness already exists and cannot be manipulated.



## **Procedure**

During fall 2009, two parallel sections of fundamental chemistry were administered a preattitude Likert scale (Appendix B), a preachievement chemistry test (Appendix A). One section was randomly chosen to be subject to textbook teaching (control) and the other context-based STS type of teaching (experimental). Following the intervention, the two groups were post tested to gauge attitudes and achievement (Appendices B and A). This was repeated in spring 2010.

## **Measures and Instrumentations**

The Chemistry Attitude Test (Salta & Tzougraki, 2004) is attached as Appendix B). It is a 30 item 5-point Likert type scaling examination that measures a student's attitudes toward chemistry.

### **Validity and Reliability With Respect to Gauging Attitudes Toward Chemistry**

Does the instrument employed measure the attitudinal construct? Trochim (1999) noted that an instrument is said to have high construct validity if it has both (a) translation or representation and (b) criterion validity. Translation validity asks if there is a link between item design and administration. For example, do instrument items cover all aspects of the construct (content validity), and do participants ascribe the same meaning and interpretation to the items as the researcher (face validity)? In regard to other forms of validity, criterion validity asks if the instrument gives results similar to another method that measures a

similar construct; discriminant validity asks whether the instrument gives results different from another method that measures a different construct, while concurrent validity asks whether it distinguishes between groups it is expected to distinguish between, and predictive validity asks whether it predicts something it should theoretically predict.

In summary, an instrument has high construct validity if it has a high content, face, concurrent, predictive, convergent, and discriminant validity.

### **The Measurement of Attitudes: Difficulties Associated With Attitude Measures**

The first obstacle in the measures of attitudes to science is that one has to take into account a wide variety of components which play a role in contributing towards an individual's attitudes towards science. Piburn and Baker (1993) incorporated a wide gamut of components in their measures of attitudes to science that included but not limited to the following: (a) the perception of the science teacher; (b) anxiety toward science; (c) motivation towards science; (the motivational construct is beyond the scope of my study) (d) enjoyment of science; and (e) the nature of the classroom environment.

The second obstacle is that the students may approach the questions with a mindset different from that of the researcher. The third obstacle is that attitudes essentially measure the subject's expressed preferences and feelings towards an object. These expressed preferences and feelings may not necessarily be reflected in the behavior the student actually exhibits. For example, a student may express

that he/she has an interest in science but avoids publicly demonstrating it among his/her peers who regard science as not being an “in thing.”

Keeping the above obstacles in mind, in order to tackle the issue of validity threat, the researcher chose Salta and Tzougraki (2004) Likert scale that encompasses a broad range of attitudinal components to gauge attitudes toward chemistry. The Likert scale used is presented in Appendix B. The instrument gauges human feelings and values. Such attitudes will affect decision-making.

The scale has a Guttman split-half of 0.90, a Spearman-Brown of 0.91, and a Cronbach’s alpha of 0.91. Content and construct validity are available for the scale. Factor analysis results of the scale are also available. Four concepts were identified: “the difficulty of chemistry course”; “the interest of chemistry course”; “the usefulness of chemistry course for students’ future career”; “the importance of chemistry for students’ life”. Therefore, four variables (subscales) could be defined: “difficulty,” “interest,” “usefulness,” and “importance.”

### **Achievement Instrument**

The Chemistry Assessment Test (Appendix A) has been designed to measure growth in domains such as chemistry concepts, chemistry processes and chemistry applications. It is a pencil-paper format 30 item, categorically scaled inventory designed to test individuals’ knowledge about fundamental chemistry, such as matter and its classification, energy, balancing chemical equations, chemical bonding, nomenclature, moles, and acids and bases. Each question is worth 1 point, giving a maximum possible score of 30.

Students will have to use the process domain, such as observation, classification, grouping and organizing, using numbers, quantification, measurement, communication, inference, formulation of hypotheses, prediction, interpretation of data and controlling variables to answer the achievement test (Enger & Yager, 2009). The test is a multiple-choice type where a question is posed and the student chooses the best answer from four options. The only relationship between items is the fact that they all measure some aspect of community college fundamental chemistry.

The achievement instrument also gives students the opportunity to take instances of chemistry concepts in everyday experience, apply the concepts and skills to everyday problems; understanding chemistry and technology involved in coal burning and nuclear power plants; evaluating media reports; decision making related to personal health using knowledge of chemistry concepts, rather than on rumor or opinion. This extends their experiences beyond the classroom.

Reliability information for the Chemistry Test instrument (Appendix A) is not available and has (to the researcher's knowledge) not been conducted. Feedback from a chemistry content specialist from the Maricopa district was taken when incorporating the questions into the test. A few of the questions were ones that had been used by the entire district over the past several years.

### **Structured Interviews**

Following the final administration of the attitude scale and achievement instrument, 5 students from the experimental group participated in structured in-

depth interviews, 3 with a medium and 2 with a low attitude shift. Their achievement scores and responses to aspects of teaching they found useful were examined. Hakes classification was used to calculate normalized gain in attitude, in which measures a greater than or equal to .7 were classified as high, measures equal to or greater than .3 but less than .7 were classified as medium, and measures less than .3 were classified as low. 5 students consented to the interview process, with no students being classified as having a high attitude shift.

I decided to interview students because Piburn and Baker (1993) conclude that student interviews provide useful information about attitudes toward science. Liking (feelings) that cannot be easily observed become more easy to notice in conversations, particularly after establishing a positive rapport with students. Though feelings cannot be observed, the emotions that prompt feeling are observable through observation of the students' body posture, body movement, anger, annoyance, joy and satisfaction (Flávia, Teixeira dos Santos, and Fleury, 2003). Merriam (1998) suggested the use of interviews "when we cannot observe behavior, feelings, or how people interpret the world around them. It is also necessary to interview when we are interested in past events that may not be possible to replicate" (p. 72).

Guiding interview questions are attached as Appendix D. These questions focus upon chemical concepts taught, teaching approach, as well as students' desire to take a future course in chemistry. The questions are also shown in the Data Collection section, and serve to explore students' attitude toward chemistry

and the teaching of chemistry. The qualitative research design incorporated Maxwell's components of the purpose of the study (gauging attitudes and achievement), the research question (what aspects of the teaching approach were/were not useful, and why; what their course taking priorities going to be), the conceptual context (highlighting the pilot study), methods (involves the participants, timeline, access), and validity (why should I believe in the results of your study). Going back and forth between the interview data and the patterns that may emerge from it is iterative (tacking) and is very critical for continually refining the design. Qualitative analysis was used to examine the patterns for the 5 students. This is explained in detail in the data collection section. In the Data Collection section, I have also explained the steps that I took to ensure the trustworthiness of my interviews.

### **Maxwell's Qualitative Design**

Purpose: Why do I want to conduct the interview, and why should we care about the results? As has been discussed, not only is it a fact that attitudes are important, but they are negative. No study at the community college level has been documented so far that involves gauging attitudes toward chemistry, but also determining what might be impacting their future course taking priorities in chemistry.

Conceptual context: The results of the pilot study identified two negative attitudes. They were negative attitude to future enrolment in chemistry courses, and negative attitude with regard to career aspirations in chemistry.

Research Questions: What aspects of the course did they find useful/not useful? Was the teaching approach context-based for the student? What are future course taking priorities going to be? These are some questions that the structured interview questions will help answer.

Methods: The participants were students in my chemistry classes. Their age ranges from 18-53. They either have a GED, or are high school graduates. They seek non-academic credentials.

Validity: How do I tackle the validity threats to address ‘Why should I believe your results?’ (Maxwell, 1996: 4-5, in p.57, Wengraf, 2004).

Out of the 49 females (29 females from the STS group and 20 females from the control group), only 4 females from the STS group consented to the face-to-face interview. There was also 1 male from the STS group that gave his consent to the face-to-face interview. The remaining 25 females from the STS group, and 20 females from the control group consented to provide written responses to the four interview questions.

### **Instructional Strategies**

Participants consisted of 75 community college chemistry students who were enrolled in fundamental chemistry between fall 2009 and spring 2010. Each class period met once a week for 2 hours. The curriculum was run over a period of 10 weeks in fall 2009 and 10 weeks in spring 2010.

Table 1 contrasts the two instructional strategies, namely STS and textbook approaches. The two approaches differ in many important features. The philosophical point of view of learning and the utilized teaching strategies are different for both.

For both groups, the chemistry concepts and time frame were kept the same (Appendix E). This justifies the use of the same set of attitude and achievement instruments for both groups. The curriculum used in the context-based type of teaching is shown in Appendix F.

Table 1

*Outline of Differences Between Textbook Teaching and Context-Based Teaching*

Textbook	Context-based (STS)
Survey of major concepts found in Corwin and Zumdahl textbooks	Taking the concepts to make a connection with problems that have a societal impact
Use of standard problems in the form of strings of formulas from the textbook	Students use human and material resources to locate information for problem solving
Teacher PowerPoint lecture	Students seek information
Focus is on competencies with no connection to students' daily life	Focus is on need-to-know chemistry concepts situated in students' daily life
Students problem solve textbook worksheets	Students perform citizenship roles given socioscientific scenarios
Students see processes of chemistry as something to practice as a course requisite	Students see the importance of processes as skills they refine and develop to enhance learning
Students are not actively involved in the process of chemistry	Students are actively involved in the process of chemistry and see its relationship to their own actions
Students do not have an idea of identifying possible causes and effects	Students develop the skill in suggesting possible causes and effects

**Mapping of the Curriculum Onto STS and Constructivism**

As mentioned before, each week the class meeting was 2 hours. The 10-week curriculum has all three components of STS (science, technology, and



society). This enables us to take chemical concepts and situate them in a societal context, the four attributes of which are:

- (a) The social setting or surrounding or situation in which the mental encounter with the focal event occurs;
- (b) The social setting becomes the vehicle for a behavior environment in which students engage in activities;
- (c) The activities now set the stage for framing the “talk” among students;
- (d) The background knowledge. To summarize, *context* is providing the social circumstances for learning (context as social surrounding or situation) and meaning-making (context as a social activity). (p. Gilbert, 2006)

Table 2 shows curriculum topics mapping onto constructivism’s two-dimension approach. The STS stands for science, technology and society components (marked with Xs).

### **Data Collection**

As described before, one of the sections served as the treatment and one as the control group. To make sure that both groups had equal ability and were at the same starting point, I applied a pretest and posttest procedure. I administered the pretests at the beginning of the instruction and the posttests at the end of the instruction.

The duration of the intervention was 10 weeks during fall 2009 and 10 weeks during spring 2010. I decided that 10 weeks is longer than a 4-week summer intervention to look for its effect.

### **Quantitative Data (Attitudes and Achievement) Processing**

In order to answer the research questions I stated in Chapter I, the data collected in my study was analyzed as follows. To make sure that each of the two groups were equal in their ability, I applied *t*-tests to the pretest scores. When the

Table 2

*Mapping of Curriculum on to STS and Two Domain Approach of Constructivism*

Week	Activity	STS components			Aspect of constructivism (2-domain approach)
1	Building background knowledge: Classification of Matter: Substance (Element, Compound) & Mixture  In-class Assignment: Adopt an element	X	X		X
2	Atoms and Molecules  In-class Assignment: The Chemistry of Lawn Care  Combustion and Balancing Equations  In-class Assignment: Advice from Grandmother  Air Pollution and Direct Sources of the Pollutants  In-class Assignment: What is coming out of your tailpipe?  In-class Assignment: Nonroad Vehicles and Equipment  In-class Assignment: Electric Cars  Ozone: A Secondary Pollutant  In-class Assignment: Ozone Around the Clock	X	X	X	X

Week	Activity	STS components			Aspect of constructivism (2-domain approach)
	Poster Assignment: Ozone in your neighboring city				
	In-class Assignment: Advice from Grandmother				
	Air Pollution and Direct Sources of the Pollutants				
	In-class Assignment: What is coming out of your tailpipe?				
	Indoor Air Pollutants and their Sources				
	In-class Assignment: Radon Testing				
	In-class Assignment: Caesar's Last Breath	X		X	X
3	Energy for Triveca: A Socioscientific Scenario	X	X	X	X
4	The Chemistry of Global Warming	X	X	X	X
5	Assignment: Science Fiction Story				
	Assignment: Winter Woes Cartoon				
6, 7	Assignment: The CO <sub>2</sub> Emissions-Implications for Policy				
	Molecules and Moles	X	X	X	X
	Assignment: Marshmallow and				

Week	Activity	STS components			Aspect of constructivism (2-domain approach)
8,9	Pennies				
	Assignment: Trees as C Sinks; Drop in the CO <sub>2</sub> bucket? Disappearing coral reef color				
	Assignment: Kyoto Conference Humor				
	Water: Structure and Properties	X		X	X
	Assignment: Understanding Maximum Contaminant Level Goals (MCLGs) and MCLs.	X	X	X	X
	Assignment: Is your water hard?	X	X	X	X
	Assignment: Pb, Hg, and Cd in your drinking water				
	The Chemistry of Global Warming				
10	Argumentation Assignment: Regulating Arsenic in Drinking Water				
	Argumentation Assignment: Evaluating your drinking water choices. A risk-benefit analysis.	X	X	X	X
	Neutralizing the Threat of Acid Rain	X	X	X	
	Movie on Acid Rain. Discussion Questions on Acid Rain.				
	Assignment: On the Record.				

analysis revealed that the pretest scores of the treatment and control groups were not significantly different, the effectiveness of the intervention was assessed by using *t*-test on the posttest scores. I also used ANOVA to look for any hidden interactions. Pearson correlation was used to look for correlations (if any) between attitudes and achievement. The normalized gain for each student in both groups was calculated for both attitudes and achievement using:

$$\text{Normalized gain } \langle g \rangle = \frac{\text{Post} - \text{Pre}}{150 - \text{Pre}}$$

$$\text{Normalized gain } \langle g \rangle = \frac{\text{Post} - \text{Pre}}{30 - \text{Pre}}$$

### **Triveca Socioscientific Issue Data Processing**

Students were instructed to conduct research in order to find evidence supporting their responses to a set of six discussion questions which were presented to them. The responses given by students were analyzed qualitatively in order to identify themes in regard to the focus of their discussion. In the study conducted by Sadler, Barab, and Scott (2007), four separate themes were found in regard to the most significant practices for decision-making in the context of socioscientific inquiry. These consisted of the following:

1. Recognising the inherent complexity of SSI.
2. Examining issues from multiple perspectives.
3. Appreciating that SSI are subject to ongoing inquiry.
4. Exhibiting skepticism when presented potentially biased information.

While the data obtained in this study was first analyzed independently, it was decided that this same rubric should be applied to this data due to its significance and ability to appropriately explain the results obtained. In addition to devising this basic rubric, Sadler, Barab, and Scott (2007) also identified four separate levels for each of these four themes, ranging from most simplistic to most complex. In regard to the first theme, complexity, the following four levels were identified:

1. The student offers a very simplistic or illogical solution without considering multiple factors.
2. The student considers pros and cons, but ultimately frames the issue as being relatively simple with a single solution.
3. The student construes the issue as relatively complex, primarily due to a lack of information. Potential solutions tend to be tentative or inquiry-based.
4. The student perceives the general complexity of the issue based on the inclusion of multiple stakeholders, interests, and opinions. Potential solutions are tentative or inquiry-based.

Within this rubric, Level 1 individuals demonstrated the least sophisticated forms of reasoning, perceiving these issues as straightforward and simplistic, failing to incorporate competing interests. While Level 2 students did consider the pros and cons of a particular choice of action, they ended up offering simple solutions which were indicative of a failure to fully consider the circumstances at

hand. Next, Level 3 individuals generally offered tentative solutions, with a lack of information being the reason for the uncertainty present within their answers. While suggesting the issue was complex, my students did not have all the necessary information in order to make a fully informed decision. Finally, Level 4 students evidenced the most sophisticated form of reasoning of all students, demonstrating full understanding of the issues at hand, while also being aware of and incorporating the phenomenon of competing interests, biases, and differing stakeholder needs.

Next, in regard to the second theme, perspectives, the following four levels were identified:

1. The student fails to carefully examine the issue.
2. The student assesses the issue from a single perspective.
3. The student examines a unique perspective when asked to do so.
4. The student assesses the issue from multiple perspectives.

This theme focuses upon the ability of participants to examine a complex issue from multiple perspectives. At the lowest level of ability, Level 1 individuals were not able to examine the issue critically from a single perspective, and did not even approach the level of complexity required in order to critically examine this issue from multiple, differing perspectives. Level 2 students were able to examine the issue critically, but only from a single perspective. These individuals were not able to anticipate potential objections to their solutions or consider any other perspectives. At the next highest level of ability, Level 3

students were able to examine multiple perspectives when prompted by the interviewer, while Level 4 individuals examined multiple perspectives independently, without being prompted by the interviewer.

Next, the following consists of the four levels identified for the third theme, inquiry:

1. The student fails to recognize the need for inquiry.
2. The student presents vague suggestions for inquiry.
3. The student suggests a plan for inquiry focused on the collection of scientific OR social data.
4. The student suggests a plan for inquiry focused on the collection of scientific and social data.

The theme of inquiry focused upon the realization of the need for the collection of additional data in order to sufficiently explore this issue. The least advanced individuals, those providing Level 1 responses, did not recognize the need for additional information in order to further explore this issue. Instead, they stated that they had all the information required in order to decide upon a solution. Level 2 students recognized the need for additional information; however, they were only able to come up with vague recommendations for what these possible inquiries might consist of. Next, individuals offering Level 3 responses were able to outline a more specific plan of inquiry in order to help fully explore this scenario. These students would focus on either scientific or social data, but would fail to incorporate both. At the highest level of reasoning, Level 4, students



would suggest a plan of inquiry which would include both scientific and social data.

The final theme consisted of skepticism. The following presents the four levels identified for this theme:

1. The student declares no differences among stakeholders.
2. The student suggests that differences likely exist among stakeholders.
3. The student describes differences among stakeholders.
4. The student describes differences and discusses the significance of conflicting interests.

Participant students were asked to discuss what they think scientists representing two groups with competing interests would discuss in a public forum in order to explore the skepticism aspect of socioscientific reasoning in relation to this scenario. Level 1 responses, indicating the least sophisticated levels of reasoning, would suggest no differences in the reports of scientists contracted by parties with differing interests. Level 2 responses would suggest that the two groups would provide differing information, but would not be able to adequately describe the differences that they might expect to find. Next, responses categorized as Level 3 would suggest that both groups would provide differing information, but would go on to describe the kinds of information that they expect these two groups would discuss. At the most sophisticated level of reasoning, Level 4 responses would describe the differences that they expect, and discuss the

significance of competing interests in regard to how this may affect the interpretation and presentation of evidence.

### **Global Warming Writing Assignment Data Processing**

Students were given a pie chart that showed sources of CO<sub>2</sub> emissions from fossil fuel consumption in the United States for 2000. (Eubanks, L. P., Middlecamp, C. H., Pienta, N. J., Heltzel, C. E., & Weaver, G. C., 2006). They were asked to take a position on: As an individual, which sources of CO<sub>2</sub> can you control? Specifically, include a summary of your main ideas and identify evidence used to support your position and its strengths and weaknesses.

This question was posed to students as the responses from them can have implications for personal action and for setting control policies. Reading the responses revealed that students identified their own personal reactions to global warming following discussions of global warming they had seen in the news on TV or read in articles. I looked at their responses to see if students saw the sociopolitical complexity of global warming (Sadler & Klosterman, 2009).

Quality responses from 3 females and 1 male are presented and the categories that emerged are discussed in Chapter IV.

### **Interviews**

The interviews were conducted with 5 students that gave their consent to the interview process. This was held at the end of the semester in the students' natural environment (college campus), the goal of which was to elicit and express their opinions and attitudes.

As these students had jobs and depended on public transportation, they could not give me time outside of the classroom for the interview process. So, I took each 5 of them one by one for an interview of 30–40 minutes. They took place in a quiet room (Analytical Instrument room) in a relaxed atmosphere, so that the students would feel free to share their opinions. Before presenting the questions, I introduced myself, and had a short, informal conversation to help the students become accustomed to the situation. I then told the students that during the half-hour interview, each would be asked about the chemistry class. I told each student that the purpose was to learn about the students' opinions, and clarified that there are no right or wrong answers, but it was important that they be honest and true. The students' consent was then obtained so I could hand write their responses.

Twenty-five females from the STS group and 20 females from the control group consented to provide written responses to the four interview questions. As seen in the wordings of the interview questions, the questions were designed to elicit the attributes of the central factors influencing attitudes, but I took care to avoid questions that may lead the students to a single answer, and the questions were worded so that the students would feel free to express their feelings and opinions.

### **Interview Questions**

The interview questions are also attached as Appendix D. The interview included four questions:

1. What were the chemical concepts you could relate to after your course experience? Why?
2. What were the chemical concepts that did not make sense after the course experience? Why?
3. What characteristics of the teaching approach made it easy for you to make sense of the chemical concept?
4. Would you still enroll in a future chemistry course? If you do, is it because you feel “forced to”?

### **Data Processing of the Interview Question Responses**

I hand wrote and then typed up student responses to interview questions. After multiple readings of the summaries, I tried to build categories and reevaluated the categories continuously as I was processing the data. I did this because what drives the qualitative-naturalistic research method is the development of a cyclic study sequence (Spradley, 1979). Therefore I tried to do the study in circles.

After I did a primary read-through of the 5 student responses and the 25 STS female and 20 control group females’ written responses, I focused on building categories that expressed the central attributes of attitudes. I tried to see if there were any links between categories. An agreement on the categories and subcategories was reached after discussion with my advisor. I included representative quotes from the students and built explanations based on my field data and literature on science and chemistry attitudes. While doing this, I asked

myself questions such as “What is really happening in the context-based course? How does the student perceive the chemistry concepts? What does learning mean for him/her? I used Erickson’s (1986) interpretive research to understand these qualitative data.

As I had access to 45 females’ (25 STS and 20 control group) written responses, this allowed me to look for numerical trends in the students’ answers-I tried to count the number of students relating to each attribute (subcategory). In my finding shown in Chapter IV, I saw students referring to a number of attributes, which were in different subcategories.

In order to ensure that my interview results are trustworthy, firstly, I included contextual information, quotes from students, a discussion, so readers can also review the evidence I have shown. Secondly, I shared the analysis of the different categories with my advisor to strengthen the reliability of the results.

## CHAPTER 4

### FINDINGS AND RESULTS

This chapter presents and discusses the results of the quantitative analyses conducted to test the research questions presented earlier in this study. The first research question focused on the relationship between teaching approach (textbook vs. STS, namely, control vs. experimental) and students' attitudes toward chemistry. In order to explore this research question, an ANOVA was conducted in order to determine whether there was a significant difference in change in attitudes toward chemistry on the basis of teaching approach. The second research question focused on the relationship between sex and attitudes toward chemistry in the context of either teaching approach. In this ANOVA, group differences were focused upon, which included stratifying students on the basis of control or experimental group, as well as on the basis of sex. In total, this analysis compared four groups of students who were categorized on the basis of these two variables. The analysis conducted testing this research question consisted of an ANCOVA, in which pretest attitudes was included as a covariate. The focus of this analysis was on whether there were any differences in attitudes on the basis of sex of the student. Next, the third research question focused on whether there were differences in student achievement scores on the basis of the teaching approach as well as sex of the student. An ANCOVA was also utilized in order to test this research question. This analysis included pretest achievement

scores as a covariate, while group membership, defined in the context of teaching approach as well as sex of the student, was the focus of this analysis.

The research question asked whether there was a correlation between attitude and achievement in either the textbook classroom as well as the context-based classroom. Correlations were conducted in order to explore this research question.

### **Research Question 1**

The first research question consisted of the following:

RQ1: Does a context-based teaching approach improve students' attitudes toward fundamental chemistry in comparison to a textbook-based teaching approach in community college classrooms?

From this research question, the following null and alternative hypotheses were generated:

H<sub>0</sub>1: There is no significant improvement in students' attitudes toward chemistry between students receiving STS teaching and those receiving textbook teaching, as measured by the chemistry attitude survey.

H<sub>A</sub>1: There is a significant improvement in students' attitudes toward chemistry between students receiving STS teaching and those receiving textbook teaching, as measured by the chemistry attitude survey.

Since these hypotheses focus on the improvements of attitudes in students, the normalized gain (i.e., change) in attitudes was focused upon as the dependent variable. In order to test these hypotheses, a one-way ANOVA was conducted in which the independent variable consisted of group membership, both in regard to the control (textbook) and experimental (STS) group as well as on the basis of sex. Therefore, totally, four groups were included in these analyses: males in the textbook-based classroom, females in the textbook-based classroom, males in the STS classroom, and females in the STS classroom. First, the following table (Table 3) presents the means and standard deviations for the normalized gain of attitudes on the basis of group membership (teaching approach). As shown, while there does appear to be some variation in mean scores for normalized gain on the basis of group membership (students in the textbook teaching approach had lower normalized gain in attitudes than students in the STS teaching approach), standard deviations were also quite high. There may be difficulty in finding a significant effect.

Table 3

*Descriptive Statistics for Normalized Gain in Attitude Scores*

Measure	<i>N</i>	<i>M</i>	<i>SD</i>
Textbook, female	20	.018	.168
Textbook, male	14	.057	.169
STS, female	29	.115	.141
STS, male	10	.078	.165
Total	73	.066	.163



The following table (Table 4) presents the results of the Analysis of Variance conducted. This analysis failed to find a significant difference in mean values on the normalized gain of attitudes on the basis of group membership (textbook teaching vs. STS teaching).

Table 4

*ANOVA of Normalized Gain in Attitude*

Measure	<i>N</i>	<i>M</i>	<i>SD</i>	<i>F</i>
Between groups	.062	3	.021	.808 <sup>†</sup>
Within groups	1.850	70	.026	
Total	1.912	72		

<sup>†</sup> $p > .05$

Cohen's effect size *d* was calculated, giving 0.37 (medium effect size). Effect-size correlation *r* of 0.18 suggested that the change in normalized gain in attitude was one-fifth of the change in the variable representing group membership (a small correlation).

## Research Question 2

The second research question included in the study consisted of the following: While controlling for preintervention differences in Student Attitudes toward Chemistry, does sex (Male, Female) affect Student Attitudes toward chemistry in a fundamental chemistry course where a textbook-based or STS-based teaching strategy is used? This research question was written as the following hypotheses:

H<sub>0</sub>2: There is no significant difference in chemistry attitude posttest scores across sex in the textbook or STS classroom.

H<sub>A</sub>2: There is a significant difference in chemistry attitude posttest scores across sex in the textbook or STS classroom.

In order to test these hypotheses, an Analysis of Covariance (ANCOVA) was conducted in which the dependent variable consisted of posttest scores on attitudes toward chemistry, the independent variable consisted of group membership (I incorporated sex as well as control/experimental group teaching approach), and also included pretest scores as a covariate in order to control for this variable. First, the following table (Table 5) presents mean values for posttest attitude scores, along with standard deviations and sample sizes, for each group. Not much variation was found in average scores on posttest attitudes on the basis of group membership. However, the finding showed that females in STS scored higher in post attitudes than STS males; and females in textbook scored lower in post attitudes than textbook males.

Table 5

*Descriptives of Postattitude Scores of Teaching Approach and Sex*

Measure	<i>N</i>	<i>M</i>	<i>SD</i>
Textbook, female	20	94.80	5.988
Textbook, male	14	97.29	6.498
STS, female	29	99.50	5.380
STS, male	10	97.86	7.549
Total	73	97.14	6.736

The following table (Table 6) presents the results of the ANCOVA. As shown, the effect of group membership was not found to be statistically significant. Also, a covariate, pretest attitudes, was not a significant predictor of posttest attitudes.

Table 6

*ANCOVA of Posttest Attitude Scores Based on Teaching Approach and Sex*

Measure	SS	df	MS	F
Corrected model	210.12	4	52.53	1.17
Intercept	3,024.764	1	3,024.76	67.29***
Pretest attitude	29.50	1	29.50	0.66
Group	161.92	3	53.98	1.201
Error	3,056.51	68	44.95	
Total	692,065.00	73		
Corrected total	3,266.63	72		

Note.  $R^2 = .064$ ; Adjusted  $R^2 = .009$ .

\* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

Additionally, a linear regression analysis was conducted in which posttest attitudes were predicted using pretest attitudes as well as control or experimental group. These results are presented in the following table. In this analysis, neither pretest attitudes nor the variable representing treatment versus control group were found to be significant predictors of posttest attitudes. The R-squared measure for this analysis, which was found to be .047, indicates that 4.7% of the variation in posttest attitudes are explained through the use of both pretest attitudes and treatment versus control group as predictors.

Table 7

*Regression Analysis: Posttest Attitudes*

Measure	<i>B</i>	$\beta$	<i>p</i>
Pretest attitudes	.114	.117	.317
STS vs. textbook	2.424	1.565	.126
Constant	85.323	–	< .001

*Note.*  $F(2, 70) = 1.742, p = .183; R^2 = .047$ .

### Research Question 3

The third research question consisted of the following:

RQ3a: Does context-based teaching affect Student Achievement in fundamental chemistry in comparison to a textbook-based teaching approach?

RQ3b: While controlling for differences in preintervention Student Achievement Scores in a chemistry course, does sex (Male, Female) affect Student Achievement Scores in a textbook-based classroom or STS classroom?

The following hypotheses were generated from this two-part research question:

H<sub>0</sub>3a: There is no significant difference in the mean performance on achievement in chemistry between students receiving STS teaching and those receiving textbook teaching, as measured by the chemistry achievement test.

H<sub>0</sub>3b: There is no significant difference in chemistry achievement posttest scores across sex in either classroom.

H<sub>A</sub>3a: There is a significant difference in the mean performance on achievement in chemistry between students receiving STS teaching and those receiving textbook teaching, as measured by the chemistry achievement test.

H<sub>A</sub>3b: There is no significant difference in chemistry achievement posttest scores across sex in either classroom.

In order to test these hypotheses, I ran an ANCOVA in which posttest achievement scores were focused upon, but also pretest scores were included in the model as a covariate, or control variable. The independent factor, as before, consisted of the variable indicating group membership (sex and control/experimental group teaching approach). The following table (Table 8) presents the means for posttest achievement on the basis of group membership. As shown in table 8, the average post achievement score did not differ greatly on the basis of group membership.

Table 8

*Descriptive Statistics for Postachievement Scores by Teaching Approach, and Sex*

Measure	<i>N</i>	<i>M</i>	<i>SD</i>
Textbook, female	20	19.90	6.078
Textbook, male	14	21.21	5.250
STS, female	30	20.40	7.713
STS, male	10	21.50	6.023
Total	74	20.57	6.554

Cohen's effect size  $d$  for achievement was insubstantial (well below 0.1). This indicated that the STS group ( $M_1 = 20.95$ ) and textbook group ( $M_2 = 20.56$ ) did not differ based on the variable representing group membership.

Next, Table 9 presents the results of the ANCOVA. Here, posttest scores on achievement were not found to significantly vary on the basis of group membership. However, the covariate, pretest achievement, was found to be statistically significant in this model. The STS teaching approach students had higher post achievement scores than textbook teaching approach students. Also, males had higher post achievement scores than females in both teaching approaches, but no statistical significance was obtained, for post achievement scores across the two teaching approaches, or sex.

Table 9

*ANCOVA of Posttest Achievement scores by Teaching Approach and Sex*

Measure	SS	<i>df</i>	MS	<i>F</i>
Corrected model	225.60	4	56.40	1.33
Intercept	1,726.24	1	1,726.25	40.92***
Pretest achievement	201.30	1	201.30	4.77*
Group	15.65	3	5.21	0.12
Error	2,910.56	69	42.18	
Total	34,440.00	74		
Corrected total	3,136.16	73		

*Note.*  $R^2 = .072$ ; adjusted  $R^2 = .018$ .

\* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

Additionally, a linear regression analysis was conducted in which posttest achievement scores were predicted from pretest achievement scores and treatment

versus control group. In this analysis, the variable measuring the effect of being in the treatment versus the control group was not found to be statistically significant, while pretest achievement scores were found to significantly predict posttest achievement scores. These results mirror those found in the ANCOVA just presented. Specifically, in regard to this regression analysis, a one standard deviation increase in pretest achievement scores was associated with a .264 standard deviation increase in posttest achievement scores. In addition, this model had an R-squared value of .079, indicating that 7.9% of the variation in posttest achievement scores is explained through the use of both pretest achievement scores as well as treatment versus control group.

Table 10

*Regression Analysis: Posttest Achievement*

Measure	<i>B</i>	$\beta$	<i>p</i>
Pretest achievement	.518*	.264*	.025
STS vs. textbook	.602	.046	.690
Constant	15.142	–	< .001*

*Note.*  $F(2, 71) = 2.633$ ,  $R^2 = .079$ .

\* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

#### **Research Question 4**

The fourth research question in this study consisted of the following:

RQ4a: Is there a correlation between attitude and achievement in the textbook classroom?

RQ4b: Is there a correlation between attitude and achievement in the context-based classroom?

The following set of hypotheses were generated from this two-part research question:

H<sub>0</sub>4a: There is no significant correlation between chemistry attitude posttest scores and achievement posttest scores in the textbook classroom.

H<sub>0</sub>4b: There is no significant correlation between chemistry attitude posttest scores and achievement posttest scores in the STS classroom.

H<sub>A</sub>4a: There is a significant correlation between chemistry attitude posttest scores and achievement posttest scores in the textbook classroom.

H<sub>A</sub>4b: There is a significant correlation between chemistry attitude posttest scores and achievement posttest scores in the STS classroom.

In order to test these hypotheses, I ran correlations between attitude posttest scores and achievement posttest scores. Pearson's correlations were not found to be statistically significant, while Spearman's rho was found to be significant between posttest attitude scores and posttest achievement scores for the STS classroom sample. Also, Kendall's tau-b was found to approach statistical significance at the .052 level. I found the Pearson correlation to have a



probability level of .088. These findings suggest a significant association between these two measures (posttest attitude scores and posttest achievement scores) for the STS classroom sample, and allow for the rejection of null hypothesis,  $H_{04b}$ : There is no significant correlation between chemistry attitude posttest scores and achievement posttest scores in the STS classroom.

Table 11

*Correlation Between Posttest Attitude Scores and Posttest Achievement Scores by of Teaching Approach*

Measure	Posttest attitude		
	Pearson's $r$	Spearman's $\rho$	Kendall's tau-b
<u>Textbook</u>			
Posttest achievement	.113	.233	.138
<u>STS</u>			
Posttest achievement	.273a	.324*	.225b

<sup>a</sup> $p = .088$

<sup>b</sup> $p = .052$

\* $p < .05$ .

Table 12 presents a summary of the correlations conducted between pre and post attitude and achievement scores for all students in the experimental (STS) group, as well as specifically for males and females in the experimental (STS) group. Only the appropriate correlation coefficients are shown in Table 12 (correlations within pre or post scores would not be possible, while correlations can also not be conducted on two separate groups). Table 12 presents correlations between pre and post attitude scores for all students in the experimental group,

Table 12

*Correlations Between Attitudes, Achievement for Experimental Group*

	1	2	3	4	5	6	7	8	9	10	11	12
Preattitude (all exp)												
Preattitude (females)												
Preattitude (males)												
Postattitude (all exp)	.42**											
Postattitude (females)		.33										
Postattitude (males)			.85**									
Preachievement (all exp)												
Preachievement (females)												
Preachievement (males)												
Postachievement (all exp)							-.04					
Postachievement (females)								-.04				
Postachievement (males)									.01			

females in the experimental group, and males in the experimental group, along with the correlations conducted between pre and post achievement scores for all students in the experimental group, females in the experimental group, and males in the experimental group.

From Table 12, first, in regard to correlations focused on attitudes, significant correlations between pre and post attitude scores were found for all students in the experimental group as well as for males specifically. These correlations were found to be positive, indicating similarity between these two sets of scores. A significant correlation between pre attitude and post attitude scores was not found in the case of females in the experimental group. In addition, none of the three correlations conducted focusing on pre and post achievement scores were found to be statistically significant.

Next, correlations were conducted between the course grade achieved by students and post attitudes. This analysis utilized the point-biserial correlation coefficient, which is computationally equivalent to Pearson's correlation coefficient. This correlation was not found to be statistically significant, suggesting no significant association between course grade and post attitudes,  $r(49) = .062$ . In addition, two additional correlations were conducted which focused on the relationship between posttest attitudes and assignment grades. In these analyses, two assignments were focused upon in total, one focusing on the mole, and one focusing on balancing equations. Pearson's correlation coefficient was utilized in these analyses. The correlation between posttest attitudes and

grades on the assignment focusing on the mole was not found to be statistically significant,  $r(49) = .062$ , while the correlation conducted between posttest attitudes and the assignment focusing on balancing equations was also not found to be statistically significant,  $r(71) = -.068$ . The results of these analyses indicate no association between posttest attitudes and assignment grades.

### **Discussion of Quantitative Results**

In this chapter, I presented the results of the analyses done to test all research questions in this study. The first research question focused on differences in teaching approach in regard to the improvement in students' attitudes toward fundamental chemistry. The ANOVA conducted to answer this research question did not find a significant difference in the change in students' attitudes (normalized gain) on the basis of teaching approach. The second research question was on whether sex is related to student post attitudes toward chemistry in either type of classroom. The ANCOVA conducted for this research question did not find this to be the case. However, it revealed the finding that females in the STS classroom scored higher in post attitudes than males in the STS classroom; and females in the textbook classroom scored lower in post attitudes than males in the textbook classroom. Also, males from the STS group had higher post attitude scores than males in the textbook group, showing that the STS intervention had a positive effect on both sexes. However, these differences were not found to be statistically significant, indicating that these group differences may simply be due to measurement error. Next, the third research

question focused on whether there were differences in student post achievement in fundamental chemistry on the basis of either teaching approach or sex. The ANCOVA conducted did not find any significant differences. Finally, the fourth research question asked whether there was a correlation between attitude and achievement in either type of classroom. Correlations were conducted in order to explore this research question. The results found did indicate some support for a correlation between post attitude and post achievement in the STS classroom. In the following chapter (Chapter 5 Discussion and Conclusions), I have made the attempt to do a detailed discussion of these quantitative results in relation to previous literature, present the limitations of this study, and provide suggestions for future research.

### **Qualitative Results**

In addition to the quantitative analyses presented earlier in this chapter, qualitative analyses were also conducted through the use of a series of interviews. In sum, five students were given in-depth, structured interviews in order to gain additional insight relating to students' attitudes toward chemistry. In addition to this, a number of scenarios were also presented to students with their responses recorded. The first scenario, discussed below, focuses upon CO<sub>2</sub> emissions and the implications that this scenario has for policy.

## **Global Warming Writing Assignment Discussion: The CO<sub>2</sub> Emissions- Implications for Policy**

Within this scenario, students were given a pie chart that showed sources of CO<sub>2</sub> emissions from fossil fuel consumption in the United States for 2000 (Eubanks, L. P., Middlecamp, C. H., Pienta, N. J., Heltzel, C. E., & Weaver, G. C., 2006). They were asked to take a position on: As an individual, which sources of CO<sub>2</sub> can you control? Specifically, include a summary of your main ideas and identify evidence used to support your position and its strengths and weaknesses.

This question was posed to students as the responses from them can have implications for personal action and for setting control policies. The following presents a number of responses found with regard to this question.

Female 1 response: “As an individual I can control many sources of CO<sub>2</sub> consumption, maybe not on a huge scale of change but if everyone was to make a few small changes it could have an impact. One can reduce transportation like driving an SUV or taking the train, Also buy energy efficacy [sic] appliances and turn off eclectic [sic] devises [sic] and when not in use. There are many little things that one can do even in their own home to help lower emissions and their price on electricity. Government can also make laws the offer tax breaks and benefits to people willing to make these changes as incentives for change.”

Female 2 response: “As an individual I can control residential emission by organizing larger carpooling rotations, and by reforestation, planting of trees in parks, churches, communities, and empty lots. The trees planted will absorb the CO<sub>2</sub> and through the process of photosynthesis create oxygen of sugars for the plants.”

Male 1 response: “As individuals there are sources of CO<sub>2</sub> that we can control; Transportation can be controlled many different ways. First, carpooling alone would make an impact by lessening the amount of oil produced and consumed by drivers burning a horrendous amount of CO<sub>2</sub> into the atmosphere. Along with that by using public transportation, walking, and riding a bike would contribute as well. Purchasing environmentally sound vehicles like electric cars would be another helpful

way to cut back on emissions. Other sources of emissions that we can control are utility and residential production of CO<sub>2</sub>. By cutting back on direct fuel consumption used primarily for heating and cooking, along, with less consumption of electricity used for computers, electronic devices, air conditioners, etc. will drastically improve the effect of CO<sub>2</sub> emissions. It is as simple as turning the television and lights off when you are not in the room, and opening doors and windows on a nice day instead of using your heater or air conditioner.”

Female 3 response: The CO<sub>2</sub> that we can control is the factories CO<sub>2</sub> and maybe the cars’ CO<sub>2</sub>, however we cannot control what we breath [sic].

One hundred percent of the responses put students in a category, Car Consumers, in which they give the use of vehicles as the primary reason for increased CO<sub>2</sub> emissions. However, their arguments are still in the process of development.

Though students talked about the use of hybrid vehicles, such as Toyota Prius as being environmentally friendly and proposed a tax break for those that drive hybrid vehicles, none brought out the tradeoff with hybrid vehicle, in terms of its cost. Also, none talked about using an alternative to gasoline, such as ethanol, and the tradeoffs in using gasoline alternatives in their vehicles.

The first category here could be “Vehicle consumers.” A second category that emerged was “Clean planet activists.” Three students referred to planting of trees or reducing deforestation as an option to control CO<sub>2</sub> emissions. However, only one female student brought out the criticisms for using trees as C sinks in her argument, “Carbon stored in the sink can be released into the atmosphere through fires, insect outbreaks, decomposition, and respiration of plants as well as plants as well as through logging and clearance for agriculture.” The student also cited an article, Cool Antarctica, “--- in order to deal with currently generated carbon dioxide, an area of forest equivalent to 22 billion tones divided by 440 tonnes per

hectare is needed to be planted, ---.” This showed that the student was also considering the tradeoff with afforestation.

Another female, who fell in the second category of Clean Planet activists, wrote “Coral reefs are part of the foundation of the ocean chain because of global warming. Coral reefs are headed for extinction. They are precious source for food, medicine, and livelihood. Experts say, cutting back on carbon emissions could stall reef findings. 19% of coral reefs are already gone.” The student did not make the point as to why global warming might be a cause for disappearing coral reefs. In addition, she also did not cite reasons other than global warming such as fishing or pollution that might be playing a role.

The students seemed comfortable proposing options, but had difficulty discussing tradeoffs when proposing options to control CO<sub>2</sub> emissions. Only one student was able to provide criticisms for using trees as C sinks and afforestation. The intervention may not have been long enough to provide students with sufficient practice in discussing tradeoffs.

Next, I present the series of interviews that were conducted with students. The following four topics were focused upon in these interviews: the applicability of chemistry to life, difficulties with chemistry, teaching approach for chemistry, and the intent for enrolling. After the data was coded, a number of themes emerged within each of these four topics. In regard to the applicability of chemistry to life, themes consisted of professional concerns, social awareness, romance, chores, and health. Within the topic focusing on difficulties, themes



consisted of writing assignments, memorization, and problem solving. The third topic, teaching approach for chemistry, identified the themes of groups, analogies, and asking questions. The final topic, intent for enrolling, identified the themes of chemistry being a requirement, personal strengths, and personal interest/enjoyment. For the purposes of this results chapter and to maintain anonymity of my students, they will be referred to using the following labels: LA1 and LA2 for the two students who had low attitude scores, respectively, and MA3, MA4, and MA5 for the three students who were found to have moderately positive attitude scores.

### **Applicability of Chemistry to Life**

Initially, the first topic, the applicability of chemistry to life, will be focused upon. Two students mentioned the importance of chemistry in relation to their own future professions, one planning to become a veterinary technician, and one planning on becoming an engineer. The future veterinary technician focused on the importance of using formulas in real life to solve problems and in relation to daily tasks that they would encounter in their future career. This student said the following:

Learning to use formulas in real-life problem solving situations, such as Caesar's Breath helped. Being a Vet Tech, we have to calculate a lot of medications and injections to give to our patients in order to figure out the proper dose, otherwise we can be putting our patient in danger. It may even be fatal. (MA3)

This passage serves to highlight the importance that this student feels chemistry has in relation to their future career. Additionally, the future engineer focuses on

"combining compounds" specifically, stating that these types of tasks will be a regular part of their career:

I guess that would be combining compounds and seeing the outcomes. I plan on being an engineer and stuff like that will be part of my job. (LA2)

The second theme found within the topic of the applicability of chemistry to life was that of social awareness. One student mentioned the relevance of some of the concepts taught within chemistry to the issue of global warming.

Specifically, this student stated the following:

Some chemical concepts that will relate to me after this course are probably the global warming stuff. This class had us do a whole project on it and it really opened my eyes to what is going to happen. Writing a story of "Life on a frozen planet" and talking about global warming cartoons are all letting me know that global warming will affect our future. This assignment was in depth and has sort of "raised awareness" to what's going on in our planet and to come up with a solution to the problem. (MA5)

This passage strongly illustrates how taking a chemistry course really revealed to the student the importance of global warming and the relevance of chemistry to this important current issue. Additionally, the student also mentioned the importance of chemistry in that it may offer a "solution to the problem" of global warming.

Next, another theme which emerged within the broader topic of the applicability of chemistry to life was that of romance. One student suggested a correspondence between the concept that "opposites attract" in chemistry and the idea that opposites can also attract in the real world, in the sense of individual romantic relationships. Specifically, this student stated the following:

I could relate to were how the opposites attract; it works not only in chemistry but in life as well. (LA1)

The fourth theme found within the topic of the applicability of chemistry to life was that of chores. In total, two students discuss the applicability of chemistry to their chores and daily life. One student, a gardener, focused on the issue of fertilizer, and wondered whether the fertilizer that they use could contain hazardous waste. This student stated:

I love gardening and now I question if the fertilizer that I am using could have hazardous waste? The Seattle Times investigation scares me, and I would like to find out in my spare time over the summer if different brands of fertilizers being sold in Arizona contain heavy metal wastes? (MA4)

This student also mentioned an investigation relating to this issue, which further illustrates how for this student, chemistry is important and relevant in life. This student has a strong interest in this topic, as evidenced by their interest in researching whether different brands of fertilizers being sold in Arizona contain heavy-metal wastes. One student focused on the chore of laundry, illustrating how they see chemistry being related to their life:

I am now able to find chemistry in rusting nails, detergents and solvents used in my laundry and cleaning supplies. (MA4)

The fifth and final theme for the applicability of chemistry to life was that of health. Three students mentioned the importance of chemistry in relation to health. One student mentioned that after taking this course, she read that toxic nitrates are present in the groundwater in rural Arizona. She proceeded to test the level of nitrates in her grandmother's water supply, finding the level of nitrates to

be slightly below the maximum allowable limit. This student was pleased to be able to use what they have learned to help their grandmother:

I never knew the difference of metal, liquid, solids. When I read that there are toxic nitrates in ground water in rural Arizona, I decided to test the level of nitrates in my grandmother's water supply, and found the level to be slightly below the allowable limit. I showed my grandmother how we test for nitrates and how nitrate levels are monitored. I was happy that I was able to use what I learned to help my grandmother. (MA3)

Another student mentioned the properties of the elements, and discussed that within class, they focused on studying carbon. This student highlighted the importance of the strong toxicological effects of carbon:

Chemical concepts I can relate to would be a lot of the properties of elements. For "Adopt the Element," my partner and I chose carbon as it is the basis of all life as part of the DNA molecule. The activity taught me that carbon compounds show signs of strong toxicological effects. (MA3)

Additionally, one of my students focused on the relationship between what she learned in chemistry and the acid reflux experienced by her husband:

Every time I eat a Tums or pick up my husbands' prescription for Nexium to help his acid reflux, I relate it to what I learned this year in acid chemistry. (MA4)

In sum, in regard to the application of principles of chemistry to life, positive themes were found among moderately positive students, while not a single positive theme was found among students with low scores on attitudes.

### **Difficulties**

The second topic focused upon was that of difficulties. Within this topic, the following four themes were found: writing assignments, memorization, problem solving, and balancing time. First, in regard to writing assignments, one

student mentioned having difficulty understanding the writing assignments on global warming:

Honestly the writing assignments on Global Warming did not make sense. I understood chemistry in high school and took honors and we were not required to write and discuss essays. (LA2)

While this student may have understood the fundamental concepts taught, it seems that they had difficulty putting their thoughts down on paper in regard to these assignments. In addition, the data also suggest data that students had difficulties applying knowledge of chemistry to real-world problems.

For the second theme, memorization, one student mentioned having difficulty memorizing the periodic table:

I have always wanted to memorize the periodic table, and know it all the time. But I have not accomplished that. I do know the periodic table is rather large and many don't know it but I would at least like to memorize the basics. (MA3)

The next theme was that of problem solving. One student mentioned having difficulty with mols and Avogadro's number:

For whatever reason, initially I had a hard time with mols (sic) and avagadros(sic) number. I think it was setting up the problem. I certainly understood the concept that it was used scientifically to work with large amounts. I understood the analogy that it was like a dozen eggs. However, when given the problem, I had problems setting up the initial problem. It didn't help I haven't been in school for 15 years (scientific calculator). (MA4)

This student mentioned mainly having trouble initially setting up the problem and also went on to state that having been out of school for 15 years may have made the problem worse.

Another student mentioned having difficulty with chemical equation balancing, stating that they were difficult to understand, but did understand the concept toward the end of the course:

Chemical balances were hard for me to understand, but towards the end I understood it. It is just difficult to balance and it takes me some time.  
(MA5)

### **Teaching Approach for Chemistry**

The next topic, the teaching approach for chemistry, contained the following themes: groups, analogies, and asking questions. First, in regard to groups, one student mentioned the importance of working in groups within the course. Specifically, this student stated that working in groups facilitated the sharing of ideas:

When we worked in groups, it made it easy for us to share ideas as in the power plant topic (LA2).

The next theme consisted of analogies. One student mentioned the utility of analogies in everyday life, and stated that this made concepts easier to understand. This student utilized the idea of cooking eggs and baking bread in their kitchen as a way to understand a chemical change:

You would use analogies to ever (sic) day life, it made it easier to understand. For example, I now see while cooking eggs and baking bread in my kitchen, how I am doing a chemical change- everyday ingredients that I am familiar with and this helped me relate. You also provided sample exercises so we could practice on our own. (MA4)

The third theme consisted of asking questions. One student mentioned the importance of asking questions, stating that allowing questions to be asked during

class made things much easier and greatly facilitated their understanding of the subject matter:

It really made it a lot easier that you allowed us to ask questions and actually stopped and took time to really explain it to us.(MA5)

### **Intent for Enrolling**

The final topic was intent for enrolling. Within this topic, the following themes were found: the idea of enrolling being a requirement, personal strengths, and personal interest/enjoyment. First, in regard to the idea of enrolling being a requirement, one student stated that they "feel forced to" and that they "really dislike chemistry" (LA2). Another student stated the following:

I will enroll in more chemistry classes, because I have to in order to get into P.A. School, however, I never asked myself if I would take chemistry if I didn't have to. (MA4)

This student focused on the importance of taking chemistry courses for their application to a physician's assistant program. A third student stated the following:

I don't need another chemistry course, as it is not required in the nursing program. Yay! (MA5)

This student highlighted the fact that taking another chemistry course is not required in the academic program, highlighting the importance of taking chemistry as a necessary requirement.

The next theme, personal strengths, was discussed by one student. They stated the following:

No, I would not enroll, only because I am stronger in English type subjects, instead of sciences and math. (LA1)

Here, this student does not suggest that they won't be taking chemistry in the future because they dislike the subject, but instead this student feels that they are stronger in subjects closer to English as opposed to the sciences and math.

Next, the final theme consisted of personal interest/enjoyment. One student focused upon this theme, and stated the following:

I do not feel forced to. Yes, I would enroll again. I enjoyed the class and learning new things (MA3).

This individual does plan to take chemistry in the future, not because they feel forced to, but because they enjoy the subject matter.

**Frequencies of themes.** Next, this section will present a series of tables, each table focusing on a specific topic, which serves to illustrate the number of participants discussing each of the themes found along with the percentage of participants who discuss each theme in their interview. Table 13 focuses upon the first topic, the applicability of chemistry to life. Three students in total discussed the applicability of chemistry to life in relation to help, while only one student mentioned social awareness and romance, respectively.

Table 13

*Category 1: Applicability of Chemistry to Life*

Codes	# of participants to offer this experience	% of participants to offer this experience
Health	3	60
Profession	2	40
Chores	2	40
Social Awareness	1	20
Romance	1	20



Table 14 presents results focusing upon the second topic, difficulties.

Each of the three themes was mentioned by one student.

Table 14

*Category 2: Difficulties*

Codes	# of participants to offer this experience	% of participants to offer this experience
Writing assignments	1	20
Memorization	1	20
Problem solving	1	20

Table 15, presented below, focuses upon the third topic, teaching approach for chemistry. Three themes were found and one student included a response in their interview for each of the three themes.

Table 15

*Category 3: Teaching Approach for Chemistry*

Codes	# of participants to offer this experience	% of participants to offer this experience
Groups	1	20
Asking questions	1	20
Analogies	1	20

Table 16 focuses upon the fourth topic, the intent for enrolling. Three students were found to mention the theme of enrolling as a requirement, while one student each was found to mention enrolling as a component of their personal

interest and to focus on enrolling in relation to their personal strengths in academia.

Table 16

*Category 4: Intent for Enrolling*

Codes	# of participants to offer this experience	% of participants to offer this experience
Requirement	3	60
Personal interest	1	20
Personal strength	1	20

Table 17 presents a summary of all topics and themes found within the interviews of the five students in order to illustrate how each of the five individuals interviewed responded in relation to the topics and themes included here. Furthermore, this table (Table 13) also presents a comparison between the responses of those found to have low attitudes and those found to have moderately positive attitudes. As shown in the table, there appears to be a fairly wide dispersion in responses among these individuals.

In addition to these data, face-to-face interviews were also conducted. Out of the 49 females (29 females from the STS group and 20 females from the control group), only 4 females from the STS group consented to the face-to-face interview. There was also 1 male from the STS group that gave his consent to the face-to-face interview. The remaining 25 females from the STS group, and 20 females from the control group consented to provide written responses to the four

Table 17

*Distribution of Themes: Comparison Between Low and Medium Attitudes*

	LA1	LA2	MA3	MA4	MA5
<u>Category 1</u>					
Health			XX	X	
Profession		X	X		
Chores				XX	
Social awareness					X
Romance	X				
<u>Category 2</u>					
Balancing equations					X
Writing assignment		X			
Memorization			X		
Problem-solving				X	
<u>Category 3</u>					
Groups		X			
Asking questions					X
Analogies				X	
<u>Category 4</u>					
Requirement		X		X	X
Personal strength	X				
Personal interest			X		

interview questions. The following four questions were the interview questions used:

1. What characteristics of the teaching approach made it easy for you to make sense of the chemical concept?
2. What were the chemical concepts you could relate to after your course experience? Why?

3. What were the chemical concepts that did not make sense after the course experience? Why?
4. Would you still enroll in a future chemistry course? If you do, is it because you feel “forced to”?

### **STS Group Females’ Responses to Interview Question 1**

Out of the 30 females in the STS group, only four females consented to the process of interview. When the remaining 26 females’ written responses to this question were analyzed, perception of the chemistry teacher emerged as a category. This category was further subdivided into subcategories based on the words used by students in their responses:

**Subcategory 1: Characteristics of a good teacher.** In regard to the first subcategory, characteristics of a good teacher, representative quotations relevant to this category are presented below:

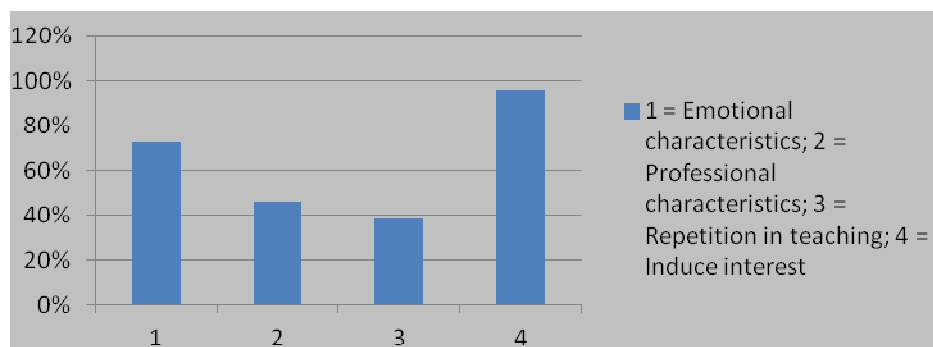
Emotional characteristics: Made chemistry a course interest and how the chemistry is important for us. She has patience to go over in the easy way, for us learn and make sense of the chemical concept.

The fact that the teacher was very engaged in the lesson and explained each step. The teacher always tried to make sure everyone understood the lesson which is what I liked most.

12 of the 26 females (46%) referred to professional characteristics in terms of not using scientific jargon and providing appropriate answers “When Ms. Perkins would use analogies to ever day life, it made it easier to understand. For example, she would use cooking in (you) [sic] kitchen everyday ingredients you were familiar with to help students relate. She also provided sample exercises so we could practice on our own.”

When the instructor fully explained it and ‘laid it out’ in a way that we can relate/understand. When my questions were answered in a way to help me better understand the material.

19 (73%) of the females referred to the teacher's emotional characteristics, and the responses with respect to emotional characteristics ranged from patience, inciting students' interest in the subject, and teacher's enthusiasm for chemistry. This is shown in Figure 1.



*Figure 1.* Percentage of STS females relating to the subcategories of teaching approach.

**Subcategory 2: Chemistry teaching method.** The main themes regarding the chemistry teaching method found were repetition of concepts and variety in teaching. A representative selection of responses relating to these two themes is presented below. 10 females (39%) referred to repetition as a means to induce understanding:

She made the work make sense. She didn't go on to the next section unless she was sure everybody understood what we were doing.

Writing everything out on the board, explaining PowerPoint slides and repeating the periodic table.

What made it easy was going over and over the problems using the same equations and just using different numbers as examples really helped out.

All but 1 (96%) of the females said that diversity in teaching methods helped create interest and understand the material. This included discussions (talking about the topic in groups), games, PowerPoint visuals, models and lab experiments

I have to say the lab was where I learned the most. I am more of a ‘hands on’ learner” and it was easy for me to understand. There is so much chemistry we use in our everyday lives.

As shown in Figure 1, which is presented above, percentages of STS females significantly varied on the basis of responses relating to the subcategories of teaching approach. Nearly 100% of the STS sample discussed topics relating to the induction of interest, category 4. Next most commonly, over 70% of these students discussed emotional characteristics. Additionally, slightly over 40% of students discussed professional characteristics, while slightly under 40% discussed repetition in teaching.

Among the control group females, only 20% control group (as opposed to 73% females in the STS group) females referred to the emotional qualities of the teacher as being important. The remaining 80% of the females in the control group said they did not find the course interesting, perhaps because emotional qualities such as teacher-student interactions were missing in the control group.

Control group female: “The openness & personality of the instructor. She is very enthusiastic & willing to answer any & all questions.”

Control group female: “Very patient in order to deal with student.”

Control group female: “The professor’s organization and her willingness to help all understand a concept. I liked the times that were given to us to practice.”

All but 3 control group females (85%) said that repetition of concepts helped them learn boring formulas. This was higher than the STS group females (39%).

With respect to variety in teaching, all control group females referred to group learning as being useful and enjoyable. Fifty percent of the control group

females also indicated that they would have liked group learning by manipulating models, watching movies, or playing with rocks. On the other hand, 96% STS females said that diversity in teaching methods helped create interest and understand the material. This included discussions (talking about the topic in groups), games, PowerPoint visuals, models and lab experiments.

Lecturing needs little more interaction. Ex. Students complete problems on board.

16 control group females (80%) also indicated that the language (chemistry) used by the teacher was not appropriate to the class level, hampering their learning. On the other hand, only 54% of STS females felt that the teacher used scientific jargon.

Control group female: “Mrs. Perkins talks fast. We often talked about things that were not related to our study. It was useful but only in a higher course. Often times I got confused.”

### **STS Group Females’ Responses to Interview Question 2**

The main theme that emerged had to do with value placed by them on chemistry studies. Two subcategories emerged from analyzing the 26 females’ responses to this question:

In regard to Figure 2, over 50% of females in the STS category, in relation to course experience, mentioned a topic or issue relating to useful knowledge on solving real-life problems, while slightly over 20% mentioned course experience as being useful in preparation for professional life.

**Subcategory 1: Useful knowledge to solve real-life problems.** The first subcategory identified focused upon useful knowledge for the purposes of solving

real-life problems. A series of quotations focusing upon this subtopic are presented below.

Many things like for example the global warming assignment help me learn that even the things we do or use can cause a negative effect to the environment. So it made me more aware of the environment. So it really helped over all.

The one in particular was about acids and bases. We had to do an experiment to see which pill works better to releave [sic] acid or heartburn. We concluded that Tums did not work very well but rolums (I think that was the name) worked very well. Now that lab was very interesting.

Well, I can say percentages of gases, such as the air contains about 75% gas[?]. CO<sub>2</sub> levels in the atmosphere. Molecules of ozone. Fossil fuel and coal. Many of our lives are affected and dealing with chemistry. Power plant energy. Coal burning. I learned about solutions and their concentrations.

Chemical reactions-in my everyday life made more sense. Examples of this would be in rusting nails, to my gardening, detergents and solvents used in my laundry and cleaning supplies. Every time I eat a Tums or pick up my husbands [sic] prescription for Nexium to help his acid reflux. I relate it to what I learned this year in chemistry.

Some chemical concepts that will relate to me is the global warming stuff. This class had us do a whole project on it and it really opened my eyes to what is going to happen. Global warming will affect our future.

The global warming assignment was pretty in depth and helps us to realize what problems are arising globally on our planet. The assignment sort of 'raised awareness' to what's going on and helps us to come up with a solution to the problem.

The pH chart is very relatable to me. I have had severe cold sores about 10 years. When people usually get 2 a year I would get 2 a month. I tried everything! Until I discovered ice tea was one of the biggest causes. I did not get them as often when I did not drink it. Then last year I started drinking a glass of orange juice every morning. This helped further get them even less. The pH chart helped me to figure out the pH of my stomach was easily changed.



My everyday life has chemistry, even if people don't think so. There is chemistry everywhere.

My favorite experience was in learn more about Ph and how is this function in our daily life, how the acid and base works together for we have balance.

Surprisingly, only 7 females (27%) talked about the importance of chemistry studies in terms of preparation for professional life.

**Subcategory 2: Knowledge for future career.** The next subcategory identified focused upon knowledge for their future career. A number of quotes relating to this specific subtopic are presented below.

The acids and bases. And there were other things like what equals a milligram or a nanometer. Good things to know since the medical field does require some knowledge.

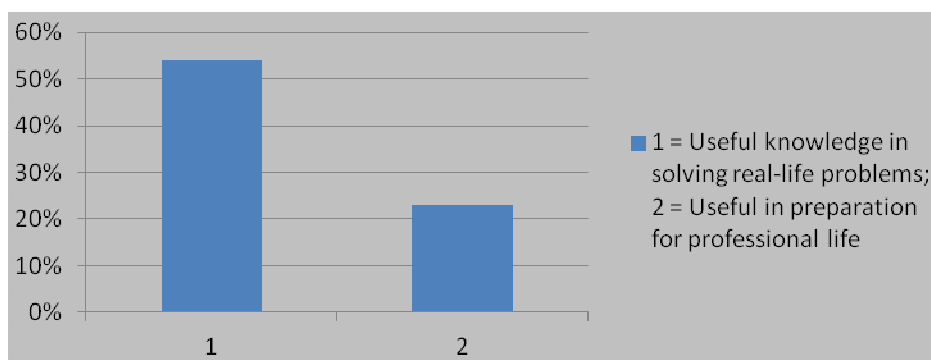
Chemical concepts I could relate to would be a lot of the formula and equations. Being a vet tech we have to calculate a lot of medication, and injections to give to our patients and eqations [sic] and formulas in order to figure out the proper dose. Otherwise we can be putting our patients in danger. It may even be fatal.

Many of the concepts are used in some form of our everyday lives especially in my field of work. I work with dialysis patients. Their phosphorus, aluminum, potassium levels are tested to determine how their bodies relate to the failure of the disease.

In my work, oxygen is used for patients that have low oxygen levels.

Some of the chemical concepts I could use after my course is converting substance because I'm going into nursing. It's very important to know what can and can't be mixed together.

As illustrated in Figure 2, among the control group females, only 2 referred to chemistry knowledge they gained useful for preparing for a professional career. All control females felt that they did not receive knowledge that would be useful in their daily life. As one student stated,



*Figure 2.* Percentage of STS females relating to the subcategories of course experience.

Chemical Bonding- difficult for me to understand. I'm still not able to explain it if you ask me, I didn't get the importance of this chapter or what it was necessary for.

Additionally, students were asked the following question:

### **STS Group Females' Responses to Interview Question 3**

Twenty STS females (80%) and 18 control group females (90%) agreed that chemical concepts of balancing equations they had trouble with. As a female STS group student stated:

The bonding of chemicals were difficult for me to grasp. How the chemicals are formed and how they go together. And also, balancing the chemical equations. A series of quotations focusing upon this issue are presented below.

Control group females wrote that scientific measurements and anything related to math equations did not make sense. "I struggle with math concepts."

Control group female: I had trouble going through the steps in the equations trying to remember what to do first.

Control group female: Balancing equations was really difficult to handle. I'm not sure why, I just couldn't grab the concept of understanding how each changed.

Control group female: Probably mostly doing math computations. It has been several years since doing any algebra.”

Control group female: The mole concept. I don’t think I will really be using this in real life. I didn’t find it really interesting.”

Control group female: Solving equations. Because I was not really prepared in the math that was required.

Control group female: All the mass and mole conversions. I think all the biochemical reactions are more interesting.

Additionally, as a separate category of response, one student in the control group mentioned having an issue with nomenclature:

Control group female: “Am still having a hard time with the nomenclature.”

Additionally, students were asked about their willingness to enroll in a future chemistry course.

#### **STS Females’ Responses to Interview Question 4**

Three STS females (12%) indicated that they would enroll in a future chemistry course for the sake of knowledge or application in daily life, and control group females, whereas 0% control group females indicated that their intent for enrolling would be for knowledge or application in real-life.

Three STS group females indicated that they would enroll in a future chemistry course (even though they were nursing majors, and the nursing program does not require additional chemistry):

STS group female: Yes. I would enroll into chemistry course in the future. Because it’s a good subject to learn and I belevie [sic] it will help me in the future with my career in nursing. Taking more chemistry course can also help me to understand what is going on throughout the whole world and atmosphere. I don’t think I’m being force to continue in a chemistry

course because in the end it's my choice to continue on or not. But if it was up to me I would continue on to the next chemistry course.

STS group female: I would enroll in the future into chemistry course because it will help me understand more of the concepts I had trouble in. No I would not feel forced to enroll into another chemistry course. I really enjoyed your class. It was a good experience.

STS group female: Yes, not because I'm forced to but because I want more knowledge.

STS group female: no, even though it is interesting, I will not take again unless I have to. I could see some people in the class really got it & liked it. I was not one of them.

All control group females wrote that enrollment into a future chemistry course depended on their major, or the number of meeting days in a week for the course or for review or brushing up, or if they felt that they had a natural talent in the class. It was not an issue of feeling "forced to." For example, one control group female wrote, "It depends on my major. Right now I am concentrating on my nursing BSN and on mortuary science. So it depends. I do not feel forced about taking chemistry courses. As several additional students stated:

Control group female: "No, I would not enroll into a future chem. Course. I don't feel that I have a natural talent in the class."

Control group female: "I don't need to take a chemistry class anymore."

In the following chapter (Chapter 5 Discussion and Conclusions), I will make the attempt to do a detailed discussion of these qualitative results in relation to previous literature, present the limitations of this study, and provide suggestions for future research.

## Data From Online Discussion Project

In order to provide this study with additional data, students were also asked the following. *At a town meeting, a group of scientists employed by the mayor and another group of scientists employed by the concerned citizens group provided expert opinions on the power plant issue. What do you think each group said?* This scenario constituted the “Triveca” scenario, which serves to determine the complexity and level at which students think about a variety of issues. The following paragraph is a sample from a low attitude (LA2) STS male from an online discussion project on coal burning vs. nuclear power plant:

We believe that the scientist from the local citizen community would basically say more of an ethical type argument. We think they would bring up all the “what if’s,” like what if a child touched some radiation, what if radiation got into the water supply. We also believe the citizen scientists would also have scientific research backing up these “what if” claims. They would probably mention the explosion at Chernobyl, and the likelihood of that happening again. They would also bring up the damaging effects a radiation leak could have on the environment.

The scientists from the mayor’s office would most likely appeal to the citizens from a scientific point of view only. They would state the facts of Chernobyl, but also state how far scientists have come from that incident. They would state the risks of having a nuclear power plant in the neighborhood, but also make a huge emphasis on the positive nuclear power poses these days. Scientists would talk about how careful attention has to be given to pressure, temperature, and types of materials used in designing nuclear power plants. They would show the community how radiation treatment helps save lives everyday, and that not only would the nuclear plant be used for power, but for research as well.”

Though the STS male’s attitude shift was low, he enjoyed the online discussion on the nuclear power issue. In his own words, in the face-to-face interview, “When we worked in groups, it made it easy for us to share ideas as in the power plant.”

## **Discussion of the Online Triveca Activity**

Within the Triveca activity, the first theme focused upon was that of complexity of SSI. In regard to this study, this theme focused specifically upon the extent to which my students perceived the inherent complexity and the problem with which they were presented. As presented in the previous section, the following rubric, used by Sadler, Barab and Scott (2007) was utilized, which consisted of the following four categories of students in regard to complexity:

1. The student offers a very simplistic or illogical solution without considering multiple factors.
2. The student considers pros and cons, but ultimately frames the issue as being relatively simple with a single solution.
3. The student construes the issue as relatively complex, primarily due to a lack of information. Potential solutions tend to be tentative or inquiry-based.
4. The student perceives the general complexity of the issue based on the inclusion of multiple stakeholders, interests, and opinions. Potential solutions are tentative or inquiry-based.

The majority of students in this sample were found to appreciate the complexity of this scenario. In general, students could be categorized as providing either Level 2, Level 3, or Level 4 responses. The following presents an example of a Level 1 response:

No because coal burning is inexpensive and the coal burning plant is already 100% operational. Verses the power plant which will take years to

build and expensive to fund. EPA will have more laws and regulations to follow for a power plant than a coal burning plant.

As evidenced in this response, the individual did not really offer anything beyond a very simplistic solution, in addition to focusing mainly on the single factor of cost. Here, my student has not analyzed a broader set of pros and cons and fails to recognize this issue as being complex. The following quote illustrates a Level 2 response:

The problem is definitely difficult to solve. Both nuclear and coal burning power plants cause harm to their surroundings. Coal power plants harm atmospheres and nuclear power plants harm environments. Nuclear power plants can also harm people if their radioactive wastes aren't managed properly. Choosing one beside the other isn't an easy choice. The real question is which one is more dangerous after safety precaution have been taken. I personally think that the mayor should choose whichever one cause the least amount of harm regardless of what some of the local citizens may think. He really has no other choice. I also think that some claims about the danger of nuclear power plants are way over exaggerated. They are not that dangerous if managed right. The best way to solve this problem in my opinion is for the mayor to make a pie chard specifying the effects and benefits of both nuclear and coal power plants and then pick whichever one is better.

In line with the definition of a Level 2 response, this student does consider some pros and cons of both alternatives, but in the end frames this problem as having a relatively simple solution: simply focusing on which alternative is the most dangerous, without considering any other important issues. The ultimate solution suggested by my student here is too simplistic: simply summarizing the pros and cons of coal and nuclear power in a pie chart and then simply choosing “whichever one is better”. Next, the following passage presents an example of a Level 3 response:

This is a very difficult subject to approach on. One can debate the health concerns and one can debate the benefits of nuclear power plant. On the health concerns, it seems to me that everyone needs someone to blame. In all the research that I have read and gathered, there doesn't seem to be enough evidence to support claims of cancer, autism, alzheimer's or what may be the health risk of nuclear power plants. One can argue that you body in a lifetime fights cancer 6-10 times without us even knowing. the percentage of cancer cases in children and adults is minimal to conclude that the power plant is to blame.

However, one can argue that why in an accident does the government tell us to take potassium iodide? Plants can leak tritium into the ground, which then can get into our water. which are carcinogens. Some people praise the technology as a low-cost, low-emission alternative to fossil fuels, while others stress the negative impact of nuclear waste and accidents such as Three Mile Island and Chernobyl. There's a lot of discussion out there about nuclear power's role in our lives, but what's going on at the heart of these power plants?

While it is evident from this passage that this student views this issue as being relatively complex, they also allude to a lack of information in the last sentence of the above passage, in which the student asks "what's going on at the heart of these power plants?" The following passage, presented below, illustrates an example of a Level 4 response:

It is a very difficult problem because it involves a number of highly important issues: the public's health and welfare; harmful effects on the environment; the allocation of city funds which inevitably effects personal funds, to mention just a few. The city is faced with a very serious problem that concerns all the residents. Therefore the decision must come from the inhabitants and the city officials.

In this example, the student perceives the complexity of the situation and adequately considers multiple stakeholders, who have varying interests and opinions. This individual understands the difficulty in finding an adequate solution and currently favors the decision coming out of the desires of the residents of the city and its officials.



The second theme focused upon was that of perspectives. Within this theme, my students varied in regard to their ability to explore this issue from various perspectives. At a lower level of complexity, students failed to carefully examine the issue or address the issue from a single perspective. Alternatively, individuals with more advanced abilities were able to examine this scenario from multiple perspectives. Specifically, the following four levels were identified in relation to this theme:

1. The student fails to carefully examine the issue.
2. The student assesses the issue from a single perspective.
3. The student examines a unique perspective when asked to do so.
4. The student assesses the issue from multiple perspectives.

The following passage presents an example of a Level 1 response:

I agree in one hand coal burning causes pollution but at the same time it's cheaper [sic]; and on the other hand the nuclear plant doesn't cause pollution but it's more expensive and the radioactive waste is a concern for people living in the area.

This student analyzes the scenario in a very simplistic manner: they only focus on the issues of pollution and cost, and only utilize a single sentence in order to present their thoughts regarding this scenario. It is evident from reading this passage that this student fails to carefully examine this issue. The following passage presents an example of a Level 2 response:

No because coal burning is inexpensive and the coal burning plant is already 100% operational. Verses the power plant which will take years to build and expensive to fund.

While this student does briefly analyze the issue, it is really only analyzed from a single perspective, that of cost and ease of operation. By taking this simplistic view, the student easily concludes that coal should be used as opposed to nuclear power. As students were not prompted by me to assess the issue from multiple perspectives, Levels 3 and 4 were combined for the purposes of this study. The following presents an example of a Level 3 or 4 response:

Yes it is a difficult problem, because both nuclear and coal are non-renewable energy that require mining the stripping of the earth resources. Coal is a fossil fuel, which are form from dead decomposition organisms, process take millions of years. Coal-burning produces acid rain, sulfur oxide emission, carbon dioxide emission, poorer land, hazardous waste, and other problems. Nuclear power plant cycle begin with the mining of uranium which is a causing-cancer agent. Nuclear power can produce radioactive waste that can cause environment problems and cause cancer when expose to humans. Radioactive martial from nuclear power plant takes 10,000 of years to decay exponential. Choosing a side that are both a bad choice, so it extremely hard to chose a solution.

This student presents a well thought-out response that incorporates many issues. The individual understands that this is a difficult problem to solve, and tries to adequately weigh the pros and cons of both alternatives. In conclusion, the student states that making a decision either way is very difficult as both possibilities have very serious cons. It is evident from reading this passage that this individual examined this issue from multiple perspectives, constituting a Level 3/4 response.

Next, the third theme focused upon the issue of inquiry. Within this theme, responses were found to vary on the basis of the ability of individuals to recognize the need for inquiry. Individuals who had a less advanced view of inquiry failed to recognize the need for inquiry in relation to this scenario or

simply presented vague suggestions for inquiry, while those with a more advanced view of inquiry suggested a plan for inquiry which was focused on the collection of scientific and/or social data. Specifically, in regard to this theme, the following four levels were identified relating to the level of complexity:

1. The student fails to recognize the need for inquiry.
2. The student presents vague suggestions for inquiry.
3. The student suggests a plan for inquiry focused on the collection of scientific OR social data.
4. The student suggests a plan for inquiry focused on the collection of scientific and social data.

The following presents an example of a Level 2 response. Among the sample of students, no examples of the most simplistic type of reasoning, i.e., a Level 1 response, were found.

The only additional information I would gather is the reliability of the nuclear waste containment. I would also study about an area such as Chernobyl to really experience the effects of a nuclear accident from a plant.

As presented in this passage, this student only presents a single, fairly vague suggestion for inquiry. Specifically, it is suggested that information be gathered regarding the “reliability” of the nuclear waste containment, along with the effects of nuclear accidents. How this should be done or specifically what information should be collected is not noted, and no other suggestions for inquiry are presented by this student. The following passage presents an example of a Level 3 response:

We think the major information needed will be the cost. Where is the city going to get the money to build the power plant? Raise taxes, a collection or what? But we think they should raise taxes for awhile to build it. Since they raise taxes for other cause why can't they raise taxes for something good for the city.

This student does suggest a need for inquiry, and presents specific examples regarding what should be included (particularly regarding the cost for building a new power plant). However, this passage only involves a collection of a single type of data. The following passage presents an example of a Level 4 response.

The cost of solving the problem will be one of the most important factors in deciding on the power source chosen. Therefore, in addition to more extensive studies on the hazardous effects, (to both people and the environment) of coal burning plants and nuclear power plants, there should be an extensive cost analysis study done. Cost comparisons should be made on: updating coal burning plants to comply to EPA's current regulations ( which may entail building a whole new plant); building a nuclear power plant and properly disposing of the toxic waste; looking into viable alternative options to coal and nuclear power such as wind or solar power. It is obviously going to cost a great deal to solve this problem, why not use these funds to research and develop a viable option that would be safer for people and the environment. Communities are reluctant to spend additional funds on R & D if they don't have to, but this community is going to have to spend money to resolve the issue.

This student suggests a plan for inquiry, but focuses on both social as well as scientific factors. They discuss the cost as being a very important factor, and suggests conducting an extensive cost analysis, in addition to an extensive study on the hazardous effects of both coal as well as nuclear plants in regard to their effects on humans as well as the environment. In addition, this student suggests considering viable alternative options, including both wind and solar power. They suggest that due to the extensive costs that will be incurred if either coal or

nuclear power is used, these funds could instead be used to research and develop a renewable energy system.

The final theme included within this rubric focused on the issue of skepticism in the face of potentially biased information. Individuals with a less advanced view stated no difference among stakeholders, or suggested that differences likely exist among stakeholders but failed to mention any differences specifically. Students with a more advanced skeptical view either just described differences among stakeholders, or describe differences among stakeholders, and also discussed the significance of conflicting interests. Specifically, in regard to skepticism, the following four levels were utilized:

1. The student declares no differences among stakeholders.
2. The student suggests that differences likely exist among stakeholders.
3. The student describes differences among stakeholders.
4. The student describes differences and discusses the significance of conflicting interests.

The following presents an example of a Level 1 response:

I believe the scientists employed by the mayor would discuss the immediate negative effects on people from the emissions of the coal burning plant. I think the scientists from the concerned citizens group would discuss the possibility of major accidents such as the one that happened in Chernobyl and the near-accident at Three Mile Island in the U.S.

While this student discusses what the scientists employed by the mayor might discuss, and what the scientists from the concerned citizens group might discuss, no possibility is stated regarding the likelihood of these two groups of

scientists having differences in regard to their interests. Next, the following passage presents an example of a Level 2 response in regard to skepticism:

The group of scientists employed from the mayor would share the best intentions to the community, they would tell them there would be no other way to go back and start to regrow the natural resources. Since they are into making money, they would tell the citizens this is the only answer. The concerned citizens could be smart and choose their own scientists to help redevelop a green house, plant, use natural waters and other natural resources.

This student suggests that differences likely exist among stakeholders, but does not adequately go on to describe exactly what these differences might be and how precisely they might relate to the choice between these two alternatives.

Next, the following passage presents an example of a Level 3 response:

The scientists employed by the concerned citizens would most likely state their complaints about introducing a nuclear power plant into the community. Chernobyl would probably be brought up along with various concerns about radiation poisoning and fears of possible birth defects as seen in Hollywood media such as “The Hills Have Eyes.”

The mayor’s scientists however, would probably outline the benefits involved with the addition of the nuclear plant over the coal-burning plant, stating that it’s more environmentally-friendly than its counterpart while explaining that people are exposed to more radiation while flying on a commercial aircraft than while living next to a nuclear power plant.

In this example, this student adequately describes differences among stakeholders. This individual suggests that the scientists employed by the community would focus on the potential negative effects of constructing a nuclear power plant, while suggesting that the mayor’s scientists would focus on the benefits of the nuclear plant as compared with the effects of the coal burning plant. While suggesting that both groups of scientists would focus on the issue of pollution and danger, it is suggested that these two groups would focus on

different issues in their arguments. Finally, the following passage presents an example of a Level 4 response:

Scientists who are employed by the mayor may have a different opinion then they express, since they are “paid” by the mayor. I believe their speech would be prompted by their paycheck. They would most likely support the mayors choices. They may even have “scientific evidence” regarding disposing the waste in a cave would be a “safe” plan. Citizens would want to know the land wouldnt be contaminated at any point. That it would not seep in the water supply.

This student describes differences among stakeholders, and also suggests the significance of conflicting interests. Most importantly, they suggest that scientists employed by the mayor may express a different opinion than their true opinion due to the fact that they are being paid by the mayor, a very astute observation. It is also suggested that these scientists may present potentially dubious scientific evidence, as clear from the use of quotation marks, supporting their argument. However, it is also suggested that the citizens would focus more importantly on the issue of contamination and health.

In conclusion, the rubric presented in Sadler, Barab, and Scott. (2007) was utilized for the qualitative analysis of these data. This rubric was found to be very appropriate for the analysis of these data, and it was found that among these students, in general, all four levels of response in relation to complexity could be found regarding both the inherent complexity of socioscientific inquiry, the examination of this issue from multiple perspectives, the appreciation that socioscientific inquiry is subject to ongoing inquiry, and the exhibiting of skepticism when presented with potentially biased information.

## Discussion of Qualitative Results

The face-to-face interview and written responses to interview questions enabled to gain an insight into the way students perceive chemistry studies.

Characteristic factors influencing their attitude towards chemistry studies came out. The categories provided answers to four main questions:

1. What characteristics of the teaching approach made it easy for you to make sense of the chemical concept?
2. What were the chemical concepts you could relate to after your course experience? Why?
3. What were the chemical concepts that did not make sense after the course experience? Why?
4. Would you still enroll in a future chemistry course? If you do, is it because you feel “forced to”?

In response to the first question, students identified major attributes such as consideration of student's needs by the teacher, and patience with weaker students. These qualify as affective characteristics and found to be in accordance with studies on students' perception of the attributes of a 'good teacher' (Reichel & Arnon, 2009).

Seventy-three percent of STS females referred to teacher's emotional characteristics and 46% referred to professional characteristics. These results support that the teacher is one of the factors in forming and changing attitudes towards science (George, 2000).



Fifty-four percent STS females referred to chemistry knowledge gained in school as a useful knowledge for solving real-life problems, showing that they express positive attitudes towards the value of chemistry studies, with emphasis on relevance, i.e., real-life topics. To this set of students, topics such as global warming, Cesar's Breath, Acids and Bases provide relevance and are vital to significant learning. These findings are in accord with other research with high school students that found that interest in science increases when the topics involve the human body, diseases, and environment, as these provide relevance (Baram-Tsabari & Yarden, 2009; Osborne & Collins, 2001).

It is worth noting that one male STS student that participated in the face-to-face interview whose attitude gain in chemistry was low said that he did not see the point of writing assignments and cartoons on topics such as global warming. This suggests that he did not see a connection between the subjects studied in chemistry class and his everyday life. Connecting chemistry study subjects to the students' real life through narrative (stories such as life on a frozen planet) was not something he saw as relevant examples, and he did not view that knowledge and skills gained in chemistry class through such activities to be meaningful and relevant to his world. Table 3 shows that STS males had an attitude gain of 0.078, while textbook males had an attitude gain of 0.057 revealing that the STS approach had a positive effect on the male sex as well.

The LA2 STS male's online discussions on the activity on nuclear power and coal burning done revolved round inlet pressure decrease vs. volume increase.

He enjoyed this, but at the same time, in his face-to-face interview, mentioned that he did not see the point of the writing assignments. Therefore, it does not seem to matter to this LA2 STS male that information be presented in discrete disconnected pieces with no connection to their everyday life. However I do not have interview and written response results from all males to make a comparison on factors influencing their attitudes.

In the control group classroom, it was important for control group females that chemistry knowledge be tied to the students' life. As the concepts did not provide relevance, control group females' attitude scores went down. Given individual differences between female and male, it is important to the chemistry teacher to know his/her students when tying relevant knowledge to the curriculum.

The findings from attitudes of females towards chemistry fit the conclusions of Osborne and Collins (2001), who emphasize the connection between content of science class to the general world as much as possible, in order to allow all students to study and be interested in science, not just those who aspire to work in the field.

## CHAPTER 5

### DISCUSSION AND CONCLUSIONS

The purpose of this study was to analyze the impact of a context-based teaching approach (STS) versus a more traditional textbook approach on the attitudes and achievement of community college chemistry students. The sample utilized in this study consisted of 75 students, of which 35 were in the textbook sample, with the remaining 40 in the context-based group. With respect to methodology, both quantitative as well as qualitative methods were used. In addition to surveys which were conducted, five students were given structured interviews. The emergent themes were discussed and agreed upon by the graduate student researcher and her advisor.

This study grew out of a pilot study, in which very negative student attitudes toward chemistry were found. With regard to chemistry, attitudes constitute a very important issue, with only approximately 1% of high school graduates being interested in scientific careers (Leyden, 1984). More positive attitudes could increase enrolment and improve achievement of students, as well as increase interest in scientific careers (Simpson & Oliver, 1985). The STS approach may improve attitudes, as this method focuses upon student questions and interests (Yager, 1996). I proposed the STS approach, as part of this study, as a positive improvement upon the way in which fundamental chemistry courses are taught. Lord (2008) documented the need to improve the way in which college science courses are taught currently. As found by Banerjee and Yager (1995),

STS instruction is associated with an improvement in attitudes, perceived usefulness, and attitudes toward science careers. Additional research has found an association between the use of STS and positive achievement (Yager, Yager, & Lim, 2006).

While past research has identified relationships between attitude and achievement (Schibeci, 1984; Simpson & Oliver, 1990), the association between these two constructs of attitude and achievement has been found to be quite low (Papanastasiou & Zembylas, 2002). Additionally, in regard to sex, Salta and Tzougraki (2004) found no significant difference in interest, usefulness, or importance attributed to chemistry, while females were found to have less positive attitudes as compared to males in regard to chemistry course difficulty. In studying attitudes toward chemistry within this study, I used a 30-item Likert scale developed by Salta and Tzougraki (2004) in order to study the importance of chemistry in students' lives, the importance of chemistry, the difficulty of chemistry, interest in chemistry, and the usefulness of chemistry for their future career.

The first research question focused on differences in teaching approach to improve students' attitudes toward fundamental chemistry did not find a significant difference in attitudes based on the teaching approach. Though the STS approach students had higher attitude post scores, there was no significant difference between the STS and textbook students' attitude post scores. This indicates that the teaching approach used did not influence students' attitudes in

this study. This specific finding may have resulted from the fact that the approach used in this specific study did not serve to change the attitudes of students. The lack of a significant finding in this study may be related to the choice of activities, students' general attitude toward the school or toward chemistry, as well as other factors. As other studies did find a significant, positive effect of teaching approach on the attitudes of students (Banerjee and Yager, 1995; Mee-Kyeong, L. and I. Erdogan, 2007; Yager, Choi, Yager, & Akcay, 2009; Yager, Yager, & Lim, 2006), this non-significant result may be due to the fact that the community college student sample used in this study was substantially different from the samples used in these previous studies. While teaching approach was not found to significantly influence attitudes in this study, future studies conducted on a larger sample, or a sample more representative of the general student population, may find a significant association between teaching approach and attitudes.

The second research question, focusing on the relationship between sex and postattitudes toward chemistry, did not find any significant differences on the basis of sex. It was noted that females had higher postattitude scores in the STS group, while males had higher postattitude scores in the textbook group. The third research question focused on differences in postachievement on the basis of teaching approach by sex. In this analysis also, I failed to find any significant differences. I noted that males had higher postachievement scores in both groups. The fourth and final research question focused on the association between attitude and achievement in either type of classroom. These analyses did suggest a

correlation between postattitude and postachievement in the STS classroom. In summary, while an association between attitude and achievement was found in the STS classroom, teaching approach or sex was not found to influence attitudes, while sex was also not found to influence achievement. These results confirm those found in previous research indicating a modest association between attitudes and achievement, but failed to confirm research conducted illustrating differences on the basis of sex or teaching approach. These results, overall, suggest that attitudes are not expected to change on the basis of either teaching approach or gender, and that techniques other than changing the teaching approach would need to be used in order to improve the attitudes of students.

Additionally, I also conducted a qualitative analysis on the “Energy for Triveca” exercise. This consisted of a socioscientific issue which had the aim of exploring decision-making in the context of socioscientific inquiry (SSI) among students. The rubric developed by Sadler, Barab, and Scott (2007) was utilized here, which focused on the issues of complexity, perspectives, inquiry, and skepticism. As per this rubric, four separate levels of complexity with respect to these four issues were utilized in order to code responses given by participants. As I analyzed the data, I found that in general, all four levels of complexity were found in regard to these issues, with the exception of perspectives, in which I combined the third and fourth categories of responses. I did this keeping in mind that over 60% of community college students take remedial courses in reading and math, and are just beginning to assess issues from multiple perspectives. I

found that the STS students were able to apply aspects of chemistry in decision making related to socioscientific issues. This is an important finding because of the importance of SSI in establishing citizenship as an aspect of science education (Sadler, Barab, & Scott, 2007).

The final set of analyses conducted for this study consisted of additional qualitative analysis done on the interviews conducted with students. In total, five students were given in-depth, structured interviews in order to provide additional insight regarding attitudes toward chemistry. The focus of these interviews was the topics of applicability of chemistry to life, difficulties with chemistry, teaching approach for chemistry, and the intent for enrolling in additional chemistry courses. A number of themes emerged from these data. Specifically, in regard to the applicability of chemistry to life, themes consisted of professional concerns, social awareness, romance, chores, and health. In regard to difficulties, themes consisted of writing assignments, memorization, and problem solving. For the topic of teaching approach I identified the themes of groups, analogies, and asking questions. The emerging themes for the fourth topic of intent for enrolling identified were chemistry being a requirement, personal strengths, and personal interests/enjoyment. In particular, it was found that the STS approach was found to foster positive student attitudes to chemistry with regard to application of chemistry in daily life: as in the case of the female student who showed a medium shift in attitudes, who proceeded to test the level of nitrates in her grandmother's water supply, finding the level of nitrates to be slightly below the maximum

allowable limit. This student was pleased to be able to use what they have learned to help her grandmother.

In regard to the characteristics of the teaching approach which make it easy for students to make sense of concepts and chemistry, the students identified the teacher's consideration of students' needs and patience. Weaker students identified these as very important characteristics of the teaching approach. Secondly, regarding concepts they could relate to after the course, students mentioned real-life topics such as global warming. Concepts which did not make sense were associated with difficulties that students had identified. Finally, the intent of future enrollment was associated with chemistry being a requirement, personal strengths, and personal interests/enjoyment.

This set of results leads to a number of implications in regard to the nature of the chemistry course as well as teaching approach. First, students had mentioned the importance of the teacher's consideration of the needs of students, as well as patience. This finding suggests that a change in the attitude of teachers, as well as the teaching approach, may help to improve students' attitudes toward chemistry and their enjoyment of the course. As we see in Fig. 1 and Fig. 2, more number of STS students talked about positive personal and professional teacher attributes, as well as the importance of chemistry in daily life and future professional preparation. In other words, though quantitative analysis did not reveal a significant finding, from the qualitative analysis, we see how teacher attitudes and teaching approach was shaping motions of female STS students vs.



female control group students. What is worth noting is that 0% of control group females revealed that they did not gain any useful knowledge with regard to application of chemistry in daily life.

Specifically, teachers could survey students for feedback both at the beginning of the course as well as during the extent of the course in order to better understand the needs of students and hence modify their approach or teaching method based on the students' needs. Additionally, this finding also suggests that teachers should try to remain patient with students if they do not understand the material or are having difficulty with a new concept. Secondly, students mentioned that real-life topics are easier for them to relate to. This suggests that teachers should aim to incorporate current, real-world topics and issues within their lectures. One possible approach would be to initially cover a new concept or topic as presented in the textbook, followed by an illustration of the concept or topic using a current event or issue. Furthermore, teachers could rework their assignments to make them more focused on interesting, contemporary topics. Next, students identified difficulties associated with concepts which they did not understand. Within this context, it may be helpful for teachers to make sure students understand each topic before moving on within each class session. Additionally, teachers could offer extra help sessions on a regular basis, or before exams, in order to help students with the more difficult topics. This set of changes may help students to become more interested in chemistry and enjoy the course on a greater level, as well as to feel that they have the aptitude to succeed in

chemistry. This may help reduce feelings students have regarding chemistry being a requirement, all of which would help increase the likelihood of future enrollment in chemistry among students. Furthermore, these changes would also be expected to help increase student performance in chemistry.

The implications of the quantitative results are that there is a weak association between attitudes and achievement, but sex or teaching approach was not related to attitudes or achievement. The finding that teaching approach was not associated with the attitudes of students was surprising to me. I am therefore suggesting that future research should be conducted in order to further explore the relationship between these two factors.

At this point, I would like to mention that trying to gauge the correlation between attitudes and achievement is treading a wobbly path. Papanastasiou and Zembylas, 2002 have found that the home culture also to impact attitudes that in turn influences achievement. Greek students who have high achievement possess negative attitudes. This is due to the fact of burnout due to course overload. These students perceive “science is important” as it is important to self, their parents and friends. This points to the situation that may exist wherein there is achievement without interest. Due to the theoretical importance of the STS approach, along with a substantial amount of previous research illustrating positive factors associated with this teaching approach, I may be premature in concluding that this approach does not serve to improve the attitudes of students based on this study alone.

Another limitation of this study relates to the issue of sample size. By having a smaller sample size, which was under 100 students in this study, the statistical power is low, which leads to a lower likelihood of correctly rejecting a false null hypothesis (Murphy, Myers, & Wolach, 2008). With regard to the analyses conducted for this study, this means that there is a higher likelihood of a non-significant finding in the statistical tests conducted in situations whether there did in fact exist a relationship between the variables included in the analysis (Murphy, Myers, & Wolach, 2008). Future studies could improve upon this issue by including a larger sample size, therefore achieving higher statistical power.

Also, the length of the intervention used in this study may also have contributed to the relative lack of significant findings. Future research could incorporate a more lengthy intervention in the hope of uncovering greater significant results. Finally, it is also important to consider the nature of the sample itself. Previous research, while focusing on college students, has not generally focused upon community college students specifically. As community college students were the specific focus of this study, this distinction in regard to the sample used may serve to explain the lack of many significant findings in regard to this current study, as well as the sharp differences found between the results of this study and previous research.

Additionally, it may also be possible that community college students, as a group, may have been resistant to the intervention as compared with four-year college or university students. Factors including their socioeconomic status,

educational background, or future goals and plan career paths may have made them more resistant to change. Specifically, having a lower socioeconomic status, and hence a poorer educational background, may lead to more negative attitudes toward chemistry which were more resistant to change as a result of the intervention. Furthermore, if these students are more likely to have future goals and planned career paths outside of science/academia, they may also be more likely to enter the classroom with rigid, negative attitudes were chemistry, viewing it simply as a class to get through as they work toward these goals.

Being older non-traditional students, being more likely to work while a student, and a lack of family support may also serve to make community college students more resistant to the intervention. Older students may already have taken chemistry earlier in their educational career, and therefore may have attitudes that are resistant to change. Additionally, students who work in addition to their studies, potentially having no financial support from their family, may have even less interest in chemistry than the average student, having to also focus on their employment and on financial matters. For these reasons, any interventions may have less of an effect on these students. Additional research which includes 4-year college students, graduate students, or secondary students may uncover more significant or differing results.

Added to this, a significant percent of the classroom students are Latinos, who tend to enroll in this inner city college more than any other group. The percent that complete a postsecondary degree is lower than 50%. Though these

students have interest, more might have to be done with them with regard to self-efficacy, to be able to see achievement. In addition, the students need lot more assistance with regard to rehearsal, elaboration, summarization strategies, and metacognitive approaches. As these cognitive strategies share a reciprocal relationship with motivation, the intervention with this group of students has to be longer to be able to see achievement.

Future studies could include a nested design, consisting of 6 STS teachers teaching 6 groups of students. After this, a random sample of 10 STS students from each teacher's group could be tested. All males in one group, all females in another is another option to look for gender differences. Teachers are the analytic unit here. A random sample of students would also increase external validity by incorporating a sample in which the results found could be generalized to a larger population.

Additional factors such as adaptive learning beliefs (self-efficacy, task utility, goal orientation), as well as students' cognitive strategies (rehearsal, elaboration, summarization, and metacognitive approaches) would have to be taken into account to see if there is an impact on community college student achievement in STS classrooms.

The data from the "Energy for Triveca" exercise supports the conclusion that community college students evidenced a wide range in the complexity of socioscientific reasoning. While some students gave simplistic responses, many of these students presented responses that indicated high levels of complexity,

suggesting that more advanced socioscientific reasoning can be expected from a substantial proportion of beginning college students. Finally, the last set of analyses provided details regarding student attitudes associated with the topics of applicability of chemistry to life, difficulties with chemistry, teaching approach for chemistry, and the intent for enrolling. This analysis found a number of themes in the data, providing a substantial amount of information relating to possible improvements which could be made by the researcher, as a teacher, in teaching approach and focus. By altering teaching approach and focus on the basis of these data, chemistry courses could be made more interesting for students.

By increasing student interest in the subject matter of the course itself, by way of embedding the concepts of science in the context of society, it would be expected that students' attitudes toward chemistry would be improved. Maricopa Community College District (MCCD) does not have technology as an aspect of focus in its chemistry competencies. It also remains to be seen if concepts of technology embedded in the context of society can or not bring about an improvement in student attitudes.

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APPENDIX A  
IRB APPROVAL



September 14, 2009

Re: IRB Application titled Impact of Science-Technology-Society  
Teaching vs. Textbook Teaching on Attitudes Toward Chemistry and  
Achievement in Community College Chemistry Classrooms

Dear Principal Investigator,

The Maricopa Institutional Review Board (IRB) reviewed your grant proposal on September 8, 2009 and determined that the activities outlined in the proposal do constitute human subjects research covered under 45 CFR 46, but that this research is exempt from those requirements according to 45 CFR 46.101(b) criteria #1. You may initiate your project, and it is not necessary to return to the IRB for annual review. If you decide to make changes in your project design that may result in the loss of your exempt status, then you should seek IRB approval prior to engaging in that research.

We appreciate your cooperation in complying with the federal guidelines that protect human research subjects. We wish you success in your project.

Cordially,

Maricopa IRB/College Research Review Committee

APPENDIX B

CHEMISTRY ACHIEVEMENT

Pre and Post Chemistry Test Inventory (Achievement)

Date:

Total score = 30

Code ID:

1. The air you exhale typically contains about 75% nitrogen gas. This concentration expressed in parts per million would be

- (a) 7500000
- (b) 750000
- (c) 7500
- (d) 75

2. Using your everyday knowledge of materials, a U.S. nickel coin would be classified as

- (a) compound
- (b) alloy
- (c) element
- (d) all of the above

3. Cigarette lighters burn butane,  $C_4H_{10}$ . The coefficient of oxygen in the balanced chemical equation, assuming plenty of oxygen, would be

- (a) 2
- (b) 4
- (c) 5
- (d) 13

4. The local news has just reported that today's ground-level ozone readings are right at the acceptable level, 0.12 ppm. How many molecules of ozone,  $O_3$ , are in each breath of this air? Assume each breath contains  $2 \times 10^{22}$  molecules and atoms in a breath.

- (a)  $2 \times 10^{10}$
- (b)  $2 \times 10^{11}$
- (c)  $2 \times 10^{13}$
- (d)  $2 \times 10^{15}$

5. The number of protons, electrons, and neutrons in a neutral atom of uranium-235 would be
- (a) 92, 92, 143
  - (b) 92, 143, 92
  - (c) 143, 92, 92
  - (d) none of the above
6. From the given table, what percent of the total fossil fuel carbon reservoir is from coal?
- (a) 40
  - (b) 50
  - (c) 80
  - (d) 90
7. It is estimated that volcanoes globally release about  $19 \times 10^6$  t of  $\text{SO}_2$  per year. Calculate the mass of sulfur in this amount of  $\text{SO}_2$ .
- (a) 9.5 million t
  - (b) 16 million t
  - (c) 32 million t
  - (d) 64 million t
8. The composition of coal can be approximated by  $\text{C}_{135}\text{H}_{96}\text{O}_9\text{NS}$ . A power plant burns 1.5 million tons of coal in one year. Calculate the mass of carbon (in tons) contained in 1.5 million tons of coal.
- (a) 13 million tons
  - (b) 130 million tons
  - (c) 1.3 million tons
  - (d) 1300 million tons
9. You detected 80 micrograms of lead in 5 L of water. What would be the concentration of lead expressed in parts per billion?
- (a) 16
  - (b) 400
  - (c) 8
  - (d) none of the above

10. You compare two samples of drinking water for their lead content. One had a concentration of 20 ppb and the other had a concentration of 0.003 mg/L. From this you conclude:

- (a) both have equal concentrations of lead.
- (b) the first sample has the higher concentration of lead.
- (c) the second sample has the higher concentration of lead.
- (d) insufficient information given to compute.

11. From the given graph, estimate the concentration range of  $\text{Pb}^{2+}$  in the water sample being analyzed, if the absorbance reading = 0.50.

- (a) Approximately 37-38 ppb
- (b) Approximately 40-50 ppb
- (c) Approximately 20-30 ppb
- (d) Approximately 10-20 ppb

12. If  $[\text{H}^+] = 1 \times 10^{-4} \text{ M}$ , you would classify the solution as

- (a) basic
- (b) acidic
- (c) neutral
- (d) none of the above

13. A sample of rain has a  $\text{pH} = 5$ , and a sample of lake water has a  $\text{pH} = 4$ . Your conclusion would be

- (a) The lake water is 10 times more acidic than rain.
- (b) The rain is 10 times more acidic than the lake water.
- (c) Both are basic.
- (d) Insufficient information to make a comparison of acid strength.

14. The acceptable limit for nitrate found in well water in a rural agricultural area is 10 ppm. You find the water sample to contain 350 micrograms per liter. Your concluding statement to the farmer would be

- (a) The water sample does not meet the acceptable limit.
- (b) The water sample meets the acceptable limit.
- (c) The well water is dangerous to consume.
- (d) No conclusion can be drawn from your test.

15. From the given graph of ozone concentrations at different altitudes, the approximate altitude in kilometers of maximum ozone concentration would be (1 mile = 1.61 km)

- (a) About 30 km
- (b) About 23 km
- (c) About 40 km
- (d) Insufficient information to compute

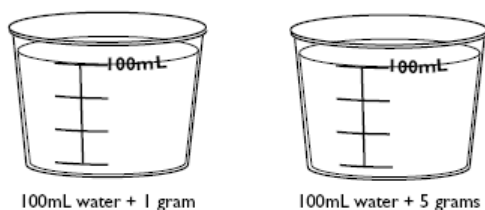
16. A cleaning solution of ammonia can be neutralized by adding an acid. What can you conclude about ammonia?

- (a) It is an acid.
- (b) It is a base.
- (c) It is neutral.
- (d) It is the same pH as water.

17. One teaspoon of sugar is added to a cup of hot tea and stirred to form a mixture. Which of the following is a solute in this mixture?

- (a) water
- (b) sugar
- (c) tea
- (d) the mixture of tea, and sugar

18. Solution A contains 1 gram of salt in 100 mL of water and Solution B contains 5 grams of salt in 100 mL of water. Which of the following statements is correct?



- (a) Solution A is more dilute than Solution B
- (b) Solution A is more concentrated than Solution B
- (c) Solution A and B have the same amount of solute
- (d) Solution A is a saturated solution

19. Which is more concentrated, (i) a solution containing 5 grams of salt in 10 grams of water or (ii) a solution containing 15 grams of salt in 85 grams of water?

- (a) (i) is more concentrated
- (b) (ii) is more concentrated
- (c) Both are equally concentrated
- (d) all of the above

20. What would be the best method for removing undissolved solid pollutants from wastewater?

- (a) precipitation
- (b) filtration
- (c) neutralization with acid
- (d) dilution with water

21. You measure the pH of some water and it is neutral. This tells you that:

- (a) the water is not polluted
- (b) there is no acid in the water
- (c) there is no salt in the water
- (d) all of the above

22. A student adds one teaspoon of salt and 1 teaspoon of pepper to 200 mL of water. The salt mixes in and disappears. The pepper does not disappear, but the water becomes a very pale brown color. Based on these observations, indicate which of the following is true?

- (a) The student will be able to remove the pepper flakes from the water by using a filter.
- (b) The student will be able to remove the salt from the water by using a filter.
- (c) The student pours the mixture through filter paper. The liquid that passes through the filter has a greater concentration of salt than of pepper.
- (d) Both a and c

23. In studying the properties of alcohol, you observe the following. Which one shows a physical property of alcohol?

- (a) alcohol in animals causes intoxication
- (b) alcohol and sodium metal generate a gas
- (c) alcohol and formic acid give a flavorful compound
- (d) alcohol boils at a temperature of 78 °C

24. Which one of the following is an example of a chemical change? Please justify your choice.

- (a) melting wax.
- (b) breaking glass.
- (c) rusting of steel wool.
- (d) crushing stone.

25. In your search for a physical change, you come across the following options. Which one presents evidence for a physical change?

- (a) Formation of sugars during photosynthesis
- (b) Acid reacting with limestone forming bubbles
- (c) grinding sucrose crystals and producing powdered sugar
- (d) Forming a reddish-brown coating on an iron nail

26. Which of the following can be a product of neutralization?

- (a) salt
- (b) base
- (c) acid
- (d) all of the above

27. Acid rain has been falling on the whole Gray Area. However, you find that not **all**, but only some of the rivers and lakes in the area are acidic. This may be due to

- (a) the lakes and rivers that are acidic are surrounded by granite
- (b) the lakes and rivers that are not acidic are surrounded by limestone
- (c) Both a and b
- (d) None of the above

28. You found the water sample from Lake Adaysickle to have a pH of 4, while the water sample from Gray Bay to have a pH of 6. You conclude that

- (a) the acidity of Lake Adaysickle is 1/10 the acidity of Gray Bay
- (b) the acidity of Lake Adaysickle is 10 times that of Gray Bay
- (c) the acidity of Lake Adaysickle is 100 times that of Gray Bay
- (d) All of the above



29. The emission of a coal-fired power plant is releasing sulfur and other unwanted pollutants in your neighborhood. Your recommended solution to the problem is to

- (a) make the smokestack of the plant taller
- (b) make the smokestack of the plant shorter
- (c) remove the smokestack
- (d) request the plant to put “scrubbers” on its smokestack

30. A blood sample has a pH of 7.45. Which of the following describes the proton concentration?

- (a) Between  $10^{-7}$  and  $10^{-8}$
- (b) Between  $10^{-6}$  and  $10^{-7}$
- (c) Between  $10^7$  and  $10^8$
- (d) Between  $10^{-4}$  and  $10^{-5}$

APPENDIX C

CHEMISTRY ATTITUDE TEST CAT

**DIRECTIONS:** The statements in this survey have to do with your feelings about chemistry instruction in school and the importance of chemistry in your life. Please read each statement carefully, and circle the number that best expresses **your own** feelings.

Remember that this is not a test, and there are no “right” or “wrong” answers. Please respond to every item.

1. To what extent do you agree or disagree with each of the following statements about chemistry? (*Circle one number on each line.*)

**1 = Strongly disagree**

**2 = Disagree**

**3 = Not sure**

**4 = Agree**

**5 = Strongly agree**

1. I like chemistry course more than the others.
2. Chemical symbols are like Chinese to me.
3. I would like to have chemistry lessons more often.
4. The progress of chemistry is responsible for many environmental problems.
5. Chemistry knowledge is useful to interpret many aspects of our everyday life.
6. Chemistry course is not related to the other courses.
7. I solve chemistry exercises very easily.
8. Chemistry course helps the development of my conceptual skills.
9. During chemistry lessons, I am bored.
10. Chemistry knowledge will be useless after my graduation.
11. Chemistry knowledge is essential for understanding other courses.
12. The progress of chemistry improves the quality of our lives.
13. Chemistry is our hope for solving many environmental problems.
14. My future career is independent from chemistry knowledge.
15. The progress of chemistry contributes to the development of a country.

16. Chemistry is a very sophisticated subject for our compulsory education.
17. I make many efforts to understand chemistry.
18. I find the use of chemical symbols easy like walk-over.
19. The profession of a chemist is one of the less attractive.
20. Every citizen must have chemistry knowledge.
21. I hate chemistry courses.
22. Chemistry knowledge is necessary for my future career.
23. I would like to have fewer chemistry lessons.
24. I understand the chemistry concepts very easily.
25. I find the chemistry course very interesting.
26. When I try to solve chemistry exercises, my mind goes blank.
27. People are indifferent to chemistry applications.
28. The progress of chemistry worsens the conditions of living.
29. I am incapable of interpreting the world around me using chemistry knowledge.
30. I would like to become a chemist when I finish school.

## APPENDIX D

### FEEDBACK

Please describe in detail, with examples what aspects of the classroom teaching helped you learn and what aspects did not. Your feedback will be very helpful in making necessary modifications.

Aspects of the teaching that helped you learn(+ delta)	Aspects of the teaching that helped you Learn (- delta)
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APPENDIX E

GUIDING INTERVIEW QUESTIONS

Interview question	Research question it answers
What were the chemical concepts you could relate to after your course experience? Why?	What were the aspects of the course that were useful?
What were the chemical concepts that did not make sense after the course experience? Why?	What were the aspects of the course that were not useful?
What characteristics of the teaching approach made it easy for you to make sense of the chemical concept?	Was the teaching approach context-based for the student?
Would you still enroll in a future chemistry course? If you do, is it because you feel “forced to”?	What are the student’s course taking priorities?



APPENDIX F

CURRICULUM COMPARISON: STS & TEXTBOOK

## Topic: Water: Structure and Properties

### Competencies:

1. Students understand the important properties of water and how it can be put to wise use by mankind.
2. Students understand the behavior of certain substances in water and have the ability to measure the amount of substances.
3. Students have the ability to explain the laboratory process and large scale process for the purification of water.

Textbook	STS
Text chapter/section:	STS
Theme: Water quality	
Water (chapter 13)	How does water get contaminated?
a. Why do we study water?	
Understanding maximum contaminant Volume of its use (MCLGs) and MCLs	Level goals
Destination of waste	Is your water hard?
b. How do we study water?	Pb, Hg, and Cd in your drinking water
Measurement of content ions and arsenic in drinking water	Regulating
c. What is drinking water?	Evaluating your drinking water choices: A risk-benefit analysis
Purity and safety	

APPENDIX G  
STS CURRICULUM

## **Week 1: Building background knowledge: Classification of Matter: Substance (Element, Compound) and Mixture**

Students will be given different substances such as sodium, calcium, aluminum, silver in vials to explore. They will learn why these are elements. They will then explore (sand + water; sand + sugar + water; Fe filings + sand + water) and arrive at why these would be classified as mixtures. They will be setting up and performing filtration, and evaporation.

**In-class assignment** “Adopt an Element” in which each pair of students will pick two elements of their choice, and find out what year the elements were discovered; their naturally occurring physical states; appearance; where they are found; and any two other properties, such as, toxicity, cost, uses and so on.

## **Week 2: Atoms and Molecules**

(1) Students will complete a worksheet on naming substances given their chemical formula. They will identify the substance as an element or a compound.

**In-class assignment** “The Chemistry of Lawn Care”. Student groups will be given copies of a lawn care service advertisement that quotes fertilizers it uses as “a balanced blend of N, P, and K. They have an organic nature made up of C molecules. These fertilizers are biodegradable and turn into water.” Comment on the chemical correctness of this information. Are there any changes they would suggest.

The purpose of this assignment that deals with a topic that has an impact on society, is to see if students read reports and advertisements with a critical eye for chemical accuracy, bias, and timeliness, among other criteria.

(2) Students will complete worksheets on combustion and balancing equations.

**In-class assignment** “Advice from Grandmother”: To rid the garden of pesky caterpillars, your grandmother said, “Hammer some iron nails about a foot up from the base of your trees, spacing them every four to five inches. The Fe converts the sugary substance containing C, H, and O atoms (tree sap) into pungent ammonia that repels caterpillars. Comment on the accuracy of your grandmother’s chemistry.

(3) Using reference materials, students will study air pollution and direct sources of the pollutants (coal-fired plants that generate electricity, and automobile tailpipes).

**In-class assignment** “What is coming out of your tailpipe?” List what is coming out, including the combustion products.

Also, read EPA findings on “*Nonroad Vehicles and Equipment*” and write a brief report to summarize your readings.

**In-class assignment** “Electric Cars” There has been a promotion of the widespread development and use of electric cars as an alternative to the engine powered by gasoline. Such cars are no longer just a hope for the future, but are currently available in some areas. Divide yourselves into four groups, two for and two against and present your criteria in deciding whether to buy an electric car.

(4) Ozone: A Secondary Pollutant

**In-class discussion assignment** “Ozone Around the Clock” Students study graphs that show how hydrocarbon and O<sub>3</sub> concentrations might vary over time in a metropolitan area. Each group then decides at what time of the day are the ozone levels at their highest and lowest. What are the ozone levels like when it is dark? Why would you expect hydrocarbon levels to rise in the morning rush hour? Identify compounds that could be contributing to the hydrocarbon increase.

**Poster presentation assignment** “Ozone in your neighboring city” Using the EPA link AIRNOW, examine the color-coded data on the amount of ozone pollution in a city of your interest. Summarize your findings. Include data tables and graphs to support your points.

(5) Indoor Air Pollutants and their sources

**In-class assignment** “Radon Testing.” Summarize the dangers of Rn. Come up with ways to measure Rn levels in your home. How much does a Rn kit cost? Describe the kit.

Another pollutant students explore is CO. They perform calculations on each person’s share of CO molecules inhaled.

**Argumentation in-class assignment** “Caesar’s Last Breath” Your claim was that your lungs currently contain one molecule that was in Caesar’s last breath, based on some assumptions and a calculation. Are these assumptions reasonable?

### **Week 3: Energy**

#### **ENERGY FOR TRIVECA: A *Socioscientific Scenario***

On Bb (blackboard), student groups will do a posting of substantive responses and comments that demonstrate their careful planning and thinking about the scenario in light of the questions and their peers' comments. Each group will also respond to one of the other team's comments and add something new to their comments, in other words, critique one of the other teams. Engaging in critical debate is important. This is an opportunity for students to collectively explore socioscientific issues, and collect evidence.

A socioscientific scenario with accompanying diagram and a series of questions have been borrowed from the notion of Sadler et al (Research in Science Education, 2006). Each group comprising about 4 members will find information pertinent to the questions being posed. Each group will post its responses on discussion board section of Blackboard.

Triveca is a large city (about the size of Indianapolis) located next to the Gray Mountains. Triveca receives all of its electricity from a coal-burning power plant. Burning coal is relatively inexpensive because there are a lot of coal mines close to Triveca, but burning coal produces a lot of air pollution. The city has been fined by the Environmental Protection Agency (EPA) for air pollution violations. Because of this continuing problem, Triveca's mayor has suggested that the city build a nuclear power plant. The nuclear plant would supply all the energy needed by the growing city and would eliminate all of the coal burning air pollution. One of the problems for nuclear power plants is the production of radioactive waste products. The mayor's plan calls for the nuclear waste products to be stored in deep caves under the Gray Mountains. A local citizens group opposes the nuclear power plant because of the risk of accidents and the storage of radioactive waste products. The citizens group is concerned about the health of Triveca residents and the surrounding ecosystem. City leaders are now trying to decide what they should do.

- (a) Is this a difficult problem to solve? Why or why not?
- (b) Based on the information you have, what decision/recommendation do you think the city should make? Why?
- (c) How do you know that is the right decision?
- (d) Can you think of a reason why someone would disagree with your solution? How would you respond to that criticism?
- (e) What additional information will you gather before making a final decision?

(f) (For Triveca) At a town meeting, a group of scientists employed by the mayor and another group of scientists employed by the concerned citizens group provided expert opinions on the power plant issue. What do you think each group said?

### **Weeks 4-6: The Chemistry of Global Warming**

Students will learn big ideas such as greenhouse gases and effect.

**Assignment:** Science Fiction Story. Each group will have an opportunity to exercise its imagination in a different climate. Assuming that the planet has an average temperature of  $-18^{\circ}\text{C}$  ( $0^{\circ}\text{F}$ ), groups will write and share on what would human life be like? A brief description of a day on a frozen planet.

**Note:** Background knowledge can be brought in particularly by students that have been residents of northern climates.

**Assignment:** Winter Woes cartoon. Do you think the comment made in the cartoon is justified? Why or why not?

### **Assignment: The CO<sub>2</sub> Emissions-Implications for Policy**

Student groups get a pie chart on the sources of CO<sub>2</sub> emissions from fossil fuel consumption in the United States for 2000. The questions have implications for personal action and for setting control policies:

(a) As an individual, which sources of CO<sub>2</sub> can you control? Explain your reasoning.

(b) Do you think that national priorities for controlling CO<sub>2</sub> emissions are set based on the rank order of percentages in the given figure? Why or why not? Explain your reasoning.

### **Week 7: Molecules and Moles**

**Assignment:** Marshmallow and Pennies. Avogadro's number is so large that analogies as the following are used: It takes Avogadro's number of marshmallows to cover the surface of the United States to a depth of 650 miles. Or, Avogadro's number of pennies were distributed evenly among the more than 6 billion inhabitants of the earth. Every man, woman, and child could spend \$1 million every hour, day and night, and half of the pennies would still be left unspent at death.

Can these claims be correct? Check one or both of your analogies, show your reasoning.

**Assignment:** (a) Trees as C Sinks. Some researchers have concluded that new forest plantations are not very efficient at sequestering C. What evidence is there for this conclusion? Does it make a difference if the new plantings replace other trees or cropland? Present your findings in a written report.

(b) Drop in the CO<sub>2</sub> bucket? How do these billions of metric tons of sequestered CO<sub>2</sub> compare with the total CO<sub>2</sub> emissions per year in the United States? Show your reasoning.

*Note:* Students will have to use graphs, combined with the population figure for the United States.

(c) Disappearing coral reef color. The brilliant beauty of coral reefs has begun to disappear in several parts of the world. What evidence is there for this statement? Are there other factors placing stress on the world's coral reefs? Present your group findings to the class.

**Assignment:** Kyoto Conference Humor. What is the humor in this cartoon? Would everyone find it amusing? Explain your reaction to this cartoon, including whether you feel it is trying to communicate a certain point of view.

## **Weeks 8-9: Water: Structure and Properties**

**Assignment:** Understanding Maximum Contaminant Level Goals (MCLGs) and MCLs. As a scientist, you are making a trip to a high school. Safe Drinking Water Act uses these unfamiliar terms. Explain what these acronyms mean and how the information helps to safeguard our drinking water. You have to also address why MCLs are not set to zero for all carcinogens.

**Assignment:** Is Your Water Hard? Students will test for level of hardness of drinking water, lab sink water at their community college campus, and water at their homes. They will also consult with a local water-softening company to find what level of hardness they typically find in their area. Both TDS and water hardness should be reported.

**Assignment:** Pb, Hg, or Cd in Your Drinking Water. Students will find out whether lead, mercury, or cadmium ions are a significant problem in drinking water where they live and on the community college campus. They will also address:

(a) If these ions are present, what are some likely sources?



(b) Are the concentrations of these ions in the water above the MCLG or MCL values?

**Argumentation Assignment:** Regulating Arsenic in Drinking Water. Early in January 2001, the Clinton administration issued a 10-ppb standard for As in drinking water, replacing the standard of 50 ppb set in 1962. The Bush administration soon after recalled the rule before it could take effect, thus reverting to the 50 ppb standard, a controversial decision.

(a) What was the reasoning behind each administration's decision?

(b) What is your response to each administration's decision?

(c) Determine whether 50 ppb is still the standard for As?

**Argumentation Assignment:** Evaluating Your Drinking Water Choices. Do a risk-benefit analysis of the characteristics of drinking tap, bottled, and filtered water. Rank the three in your order of importance. Your personal preferences can be indicated, but have to be grounded in factual information and robust reasoning.

## **Week 10: Neutralizing the Threat of Acid Rain**

Worksheet assignments on acids, bases, pH. Students also test the pH of different food materials in their kitchen and refrigerator and sink shelves.

Building background knowledge. **Movie** on Acid Rain. **Discussion Questions** on Acid Rain.