

## ABSTRACT

LAMB, RICHARD LAWRENCE. Review of the Efficacy of SAS Curriculum Pathways on Student Understanding in Chemistry. (Under the direction of Dr. Len Annetta.)

The purpose of the study is to review the efficacy of the SAS Curriculum Pathways (SIS) chemistry modules on student achievements in a high school academic level chemistry class. The research question was “Do SIS modules (numbers 692 chemical quantities, 867 chemical reactions and module 10 the mole) increase student understanding of chemistry concepts in which they are designed to teach when compared to student groups receiving traditional instruction (i.e., without the integration of the SIS modules) Comparing pre and post-tests means through a t-Test, it was found that after a unit was taught using SIS Curriculum Pathways students showed a significant ( $p < 0.05$ ) increase in understanding of the chemistry topics covered in the modules. Student journals were kept during the time frame of the study. Qualitative results suggest that there are three factors which may affect the student outcomes concerning the use of simulations: student comfort with the computer, amount and availability of information in the simulation, and the novelty of using computer simulations in a science class.

Review of the Efficacy of SAS Curriculum Pathways  
on Student Understanding in Chemistry

by  
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## **DEDICATION**

To my wife, Stacy, whose support and sacrifice has made this possible. To my daughter Trinity, who is always a source of wonder and amazement. To my grandmother and grandfather, who supported me when I needed it and who have always encouraged me to accomplish my goals. To my mother who even in the roughest times still made a place for me.

## **BIOGRAPHY**

Richard Lawrence Lamb was born to Joyce G. Lamb on September 13<sup>th</sup>, 1976. He was raised just outside of Buffalo New York by his grandparents, Myrna and Theodore Lamb. Richard's experiences in high school were very influential in pursuing studies in the sciences. After high school, Richard continued his studies at Canisius College receiving a Bachelor of Science in Biochemistry.

Upon graduation, Richard was commissioned as a Second Lieutenant in the United States Army, Chemical and Intelligence Corps. Richard served two tours of duty overseas. First in Bosnia-Herzegovina with 10<sup>th</sup> Mountain Division; and later in Afghanistan with the Joint Special Operation Task Force under Special Operations Command.

After four years of service, Richard left the military and attended North Carolina State University to obtain a general science teaching licensure. In 2004, Richard completed his licensure and has since taught Introductory Science, Academic and Honors Physical Science, AP Environmental Science and Academic and Honors Chemistry at Garner Magnet High School.

In 2006, Richard began work on his M.S. in Science Education by taking courses on a part-time basis.

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## Chapter I Introduction

Student science achievement in the United States has made significant improvements as shown in a comparison of the results from 1995 and 2003, *Trends in International Mathematics and Science Study* (TIMSS). In 1995, the United States ranked fourteenth in the world in science achievement. In 2003 the United States moved up in their achievement level and was ranked eighth in the world, with countries such as Singapore, The Republic of Korea, Hong Kong (SAR) Japan and Hungary performing significantly better than the United States. The Netherlands was ranked seventh, edging out the United States (TIMSS 1995 and 2003).

As an industrialized nation, it is important that the United States place in the upper tiers of science education, as science is one of the primary means for a country to maintain and grow its economy and influence in the world (Nye, 2004). In addition, the ability of the population to continue to improve its standard of living is tied to the ability of the country to forward itself scientifically (Nye, 2004). With the students in the United States failing to make the upper tier of scientific achievement, the United States risks falling behind the rest of the world in growth and development (Nye, 2004).

Raising the science achievement level of students falls to the science teachers and parents within the United States. Science teachers are continuously asked to teach an ever growing curriculum given less time and resources. One possible solution to this increased pressure is to increase the use of online modular supplemental instruction. With the near ubiquity of the Internet in schools, and numerous science-themed websites, it follows that

some modes of online instruction would be beneficial in raising student achievement. Through the use of simulation, animations and models, all tied to higher-thinking methodology, SIS seems to be a program which could raise student achievement.

Curriculum Pathways (SIS) is a web-based resource for grades 8-14, designed to enhance student achievement in five major disciplines: English, Social Studies, Mathematics, Science, and Spanish (SAS Institute, 2004). SIS is rooted in a framework of constructivism, or the belief that students build their knowledge based upon prior experiences and social pressures they have had in relation to topics discussed in schools. SIS seeks to build a framework for which student can work in order to improve the five major areas of education English, Spanish, science, math, and history.

**Purpose**

The purpose of the study is to review the efficacy of the Curriculum Pathways (SIS) chemistry modules on student learning in a high school academic level chemistry class. It was hypothesized that students using SIS would have a better understanding of content and thus achieves higher scores on tests designed to measure content associated with the modules when compared with students taught in a traditional lecture / lab manner; without the exposure to SIS. The research question was “Can SIS module numbers 692 chemical quantities, 867 chemical reactions and module 10 the mole increase student understanding of chemistry concepts they are designed to teach when compared to traditional instruction?” A secondary question was explored stating, “What are the factors that affect student scores for the three SIS modules?”

SIS and the constructivist approach to education complement each other well in that the student, or small groups of students, works independently to build knowledge about the selected topics, while the teacher facilitates with minimal didactic methodologies. Thus the education becomes learner centered rather than teacher centered.

## Chapter II Literature Review

### *Online Simulations in Chemistry*

Modern technologies, such as computers and multimedia websites, allow students to receive and process more information from electronic sources than they do through lecture and written forms (Reeves, 1992). As model based teaching has increased in popularity, computers have played a larger role in the classroom. (Windschilt, 2000).

Computer modeling helps students to better process information and facilitates transitioning between mental, consensus, and expressed modeling (Gilbert and Boutler, 2000). Traditional computer modeling of chemistry tends to be dependant upon molecular and atomic modeling as the basis for understanding chemistry. As the Internet develops as a teaching and learning tool, the use of non-traditional, interactive sites can be included in the education process. One of the major components of the SIS modules is the use of non-traditional chemistry models to aid in instruction. In these modules, different aspects of chemistry are topically modeled and reviewed by students.

SAS's design of the modules is built to address students' alternative conceptions, and reconstruct them through conceptual change theory. The reconstruction of student

understanding requires specific strategies such as online laboratories with an inquiry.

A meta-analysis conducted by Bayraktar in 2001 revealed that 41 of 42 studies between 1971 and 1999 showed a positive affect on student achievement as a result of the use of computer simulation in science education. A second meta-analysis conducted in 2007 by Liao of 52 studies also supported the previous research conducted by Bayraktar and concluded that computer instruction in science has a positive effect on student achievement (Liao 2007).

Flinn and Gravet (1995) showed that of the multiple types of computer instruction, the most effective style is simulation followed by tutorial. The least effective form of computer instruction is drill-and-practice (Flinn and Gravet 1995). There are studies which suggest that drill-and-practice (non interactive) in science while using computer instruction can have negative effects on student outcomes (Liao 1998). However the use of technology in the classroom can in a student centered model (interactive and dynamic) can effect two very important changes in the classroom. The first being a transition from a traditional teacher centered instruction and secondly there can be a significant increase in student perceived and actual success. (Shuell & Farber, 2001).

The more effective a teacher is at using appropriate pedagogy, the better the outcome with computer instruction because the two can reinforce each other. This is supported by a study which showed that positive technology outcomes not necessarily

due to the technology but ties to teaching methodologies. In other words computers must support the teaching methodology (Clark 1994) However, a contradictory view of this is the way in which we use technology in the classroom not the technology itself that makes a difference. In other words the methodology must support the technology. (Kozma 1994, Thornburg 1999).

As computer instruction time increases, the degree of success decreases. This is thought to be due to the Hawthorn Effect, or novelty effect, in which the student outcomes decrease due to familiarity with the use of the computer during instruction. (Bayraktar 2001). The familiarity can cause students to reduce their engagement time and thus reduce their effort while completing modules.

### **The Research Basis for Curriculum Pathways**

The development of SIS is the culmination of content and web-based technology in the classroom. Through the use of several studies, SAS (the company) makes a strong case for the use of online simulation and technologies in the classroom as a way to increase student achievement. As discussed in the “Research Basis for Curriculum Pathways,” computer-assisted instruction, interactive technologies, integrated learning systems, collaborative computer applications, and technology that uses simulations and addresses higher order thinking skills all showed positive gains for students on researcher-conducted tests, standardized tests, and national tests (Schacter, 1999).

One area that does not seem to be considered by many science education teachers is the amount of teacher professional development needed to implement the technology in the classroom. However, inconclusive findings indicate there may be other factors that

influence the impact of technology, such as student population, pedagogy, content quality and design, technology integration, and teacher preparedness (Kulik, 1994). As pointed out, poor teacher preparedness can actually have a negative impact on student performance in the classroom, as the class becomes disorganized and on task behaviors drop precipitously (Kulik, 1994). Thus the effects of technology can be masked by other factors. No Child Left Behind (NCLB) (2001) mandates that scientifically based research act as the basis for the allocation of resources and funds. However quoting (Fouts, 2000), SAS points out that there have not been a significant number of scientifically based research studies conducted on the effectiveness of technology on student achievement as defined by NCLB. Scientifically based research as defined by NCLB is research that has been replicated, tested, and applied to larger and more diverse groups of students. One possible reason for this is that the schools affected by NCLB (public schools) lack the resources and the expertise to complete studies of the nature indicated by NCLB. Only a very small number of studies are scientifically conducted or address the impact of technology as it relates to individual resources (SAS, 2004). This is further supported in the literature with the lack of evaluations addressing the impact of SIS, particularly on academic level students in a chemistry class.

The SIS White paper claims that the development of a learner centered education system with technology used as an adjunct significantly increases the achievement of students in the classroom. Research supports the (Piagetian) idea that people of all ages construct their own frameworks for understanding by processing and acting on their experiences, rather than simply accepting and retaining explanations from authority

figures (National Science Teachers Association, 2001). By incorporating technology at the correct times and places within the class, it is possible for the students to use prior knowledge to construct an understanding of the new knowledge through scaffolding provided by the teacher or by the software.

### **A multimedia approach to education**

Increasing enrollments in colleges across the United States has led to a situation in which it is possible to have anywhere from three to five hundred students in an introductory university course. This leads to low satisfaction rates among students in terms of quality of education and individual attention. In those institutions which have excessively high student enrollment in introductory level courses, the quantity of educational information delivered is increased. The numbers of students enrolled in the classes, and therefore number of degrees granted, increases; however this is at the expense of quality (Pipes and Wilson, 1996). The use of technology can be used to alleviate the overcrowding of traditional lecture classrooms at the college and high school levels. With the increase in enrollment in several areas in the country notable the south east where North Carolina is located there are parallel effects appearing at the high school level. As with the colleges, high school classes are becoming over crowded and experiencing the same decrease in quality instruction the lecture classes in the college and university setting are experiencing. Technology such as that discussed is one way to offset the increase numbers of students in the high school classroom.

The studio model developed at Rensselaer Polytechnic Institute was set up to address the need of incoming undergraduates. Traditionally, incoming freshmen in

Chemistry were placed into two lectures of three hundred to five hundred students. The students were further divided into twenty to thirty recitations of thirty students and thirty to forty laboratory sections of twenty-four students each (Pipes and Wilson 1996). Considering that traditional lecture retention rates are fairly low, the extensive use of lecture is counter productive both attitudinally and retention wise.

The studio model makes use of hands on material and simulation technology to allow students to interact with chemistry concepts and chemistry problem solving. Bloom states that active searching enhances and facilitates student education. This, coupled with high taxonomic level of thought, allows the students to experience success in chemistry. Geban, Askar and Ozkan (1992) found that the computer simulation approach was shown to be superior to the more traditional approach. In addition, it is shown that computer simulations allow for more controlled results than traditional laboratories because of the variables found in the classroom laboratory. This results in more meaningful learning.

In addition to more controlled experimental variables, the online simulations allow students to run experiments multiple times in a compressed time frame. This allows students more opportunity to experiment, adjust variables and see connections in the chemistry not otherwise available due to time constraints in a traditional model (Garrison, 1998).

Additionally, the group approach fostered by computer simulations and laboratory helps to build the social context of learning, which is vital to a constructivist. The mind is



not an isolated storage facility for facts. Instead, meaning making is accomplished within a context of peers, relationships, and the environment (Garrison, 1998). This typically will manifest itself, for the constructivist, as the need for learners to work in group settings. In these settings, individuals will be co-constructing knowledge. They need not always reach consensus as long as they are able to help each other construct, or reconstruct as necessary, the new knowledge (Pepin, 1998). This is important in the context of the study because SIS is intended to be used as a supplement to traditional instruction, where students build a consensus together in their understanding of chemistry.

### Chapter III Methods

#### **Treatment(s)**

This is a mixed methods study which incorporates the qualitative method of using student journals. Students were asked to provide written answers to 25 prompts in regards to their experiences with SIS. The quantitative portion of the study reviews student learning using a pretest and post test model. The pre and post tests can be found in appendix A. The journal prompts can be found in appendix B.

Students in an academic level chemistry class were given three online SIS modules on the following topics; The Mole (Chemical Quantities) module 692, Chemical Reactions Module 867 and Stoichiometry (Limiting Reagents Interactivity) module 10. These three modules were chosen as they are tied directly to the North Carolina Standard Course of Study (NCSCOS) competencies. The specific competencies are competencies 3.02 apply the mole concept, Avogadro's number and conversion factors to chemical

calculations, 3.03 calculate quantitative relationships in chemical reactions (stoichiometry) and 5.01 evaluate various types of chemical reactions.

Figures 1 through 4 are screen shots of SIS modules 692, 867 and 10<sup>1</sup>. Figure 1 shows the initial opening screen the students see. It shows the broad areas that are covered by the SIS. Module 692 is listed under the subsection nature of matter, Module 867 is listed under subsection chemical reactions and module 10 is listed under subsection chemical reactions.

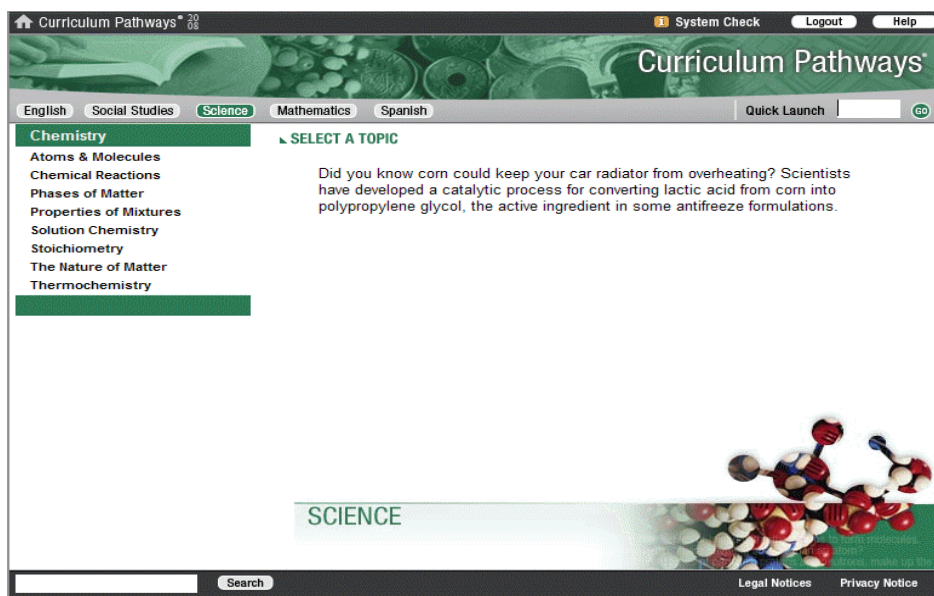


Figure 1. Screen shot of the entrance page to the chemistry portion of SIS.

Module 692 provided students information on the mole in a web quest format. The students selected the links which dealt with chemical quantities, read the section and then completed section questions on the discussed topics.

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<sup>1</sup> All screen shots and figures are used with the following permission line: Copyright © 2007, SAS Institute Inc., Cary NC, USA, All Rights Reserved. Used with permission.

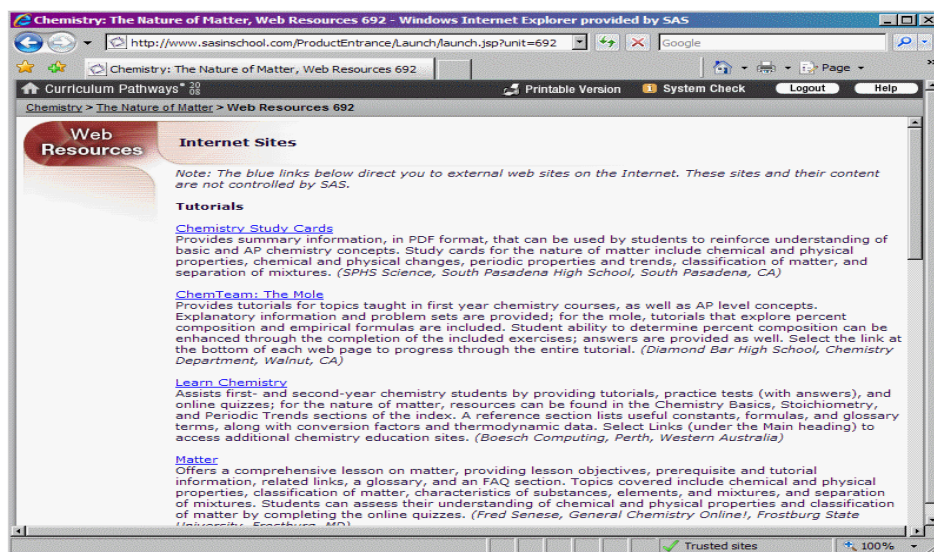


Figure 2. Screen shot of the module 692 web quest activity

Module 867 provides an online simulation of chemical reactions. Students were asked to complete a data table on precipitation reactions using the “Chemscope” online simulation. During the simulation, students build chemical reactions using graphical simulations of atoms and compounds. After properly building the chemical reaction, students were then allowed to see video simulations of the actual reactions. The student then used their observation to complete the data table. Additionally, the students were asked to derive the solubility rules based upon their observation and interactions with the “Chemscope”.

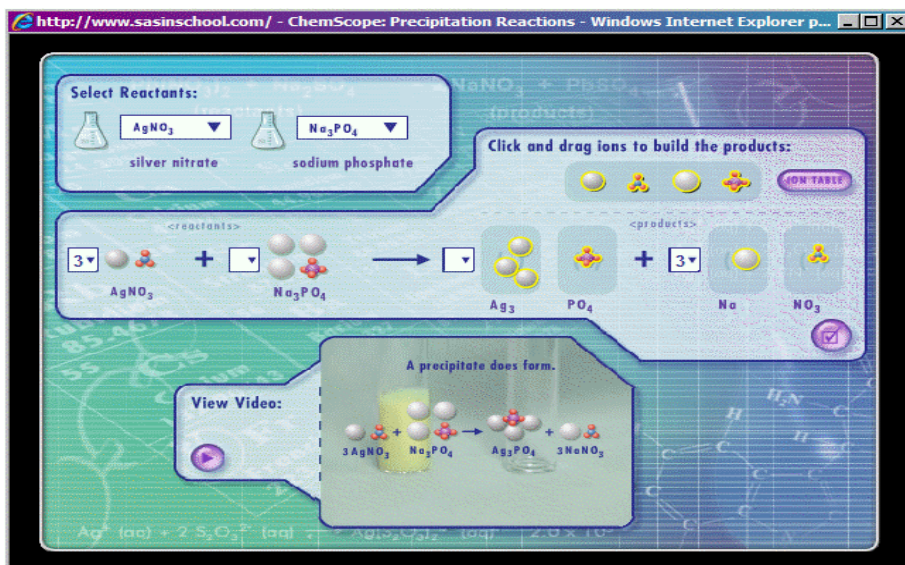


Figure 3. Screen shot of the module 867 chemscope interactivity

Module 10 provides an online simulation of stoichiometric relationships through the use of limiting reagents. Using the “Chemscope” students explored how reactant quantities affect reaction outcomes in a chemical reaction. Students completed each reaction as explained in the instructions for the interactivity and identified the limiting reagent. Based upon their identification of the limiting reagent, the students then wrote out the complete balanced equation and calculated the output of product based upon the quantity of limiting reagent on the data sheet.

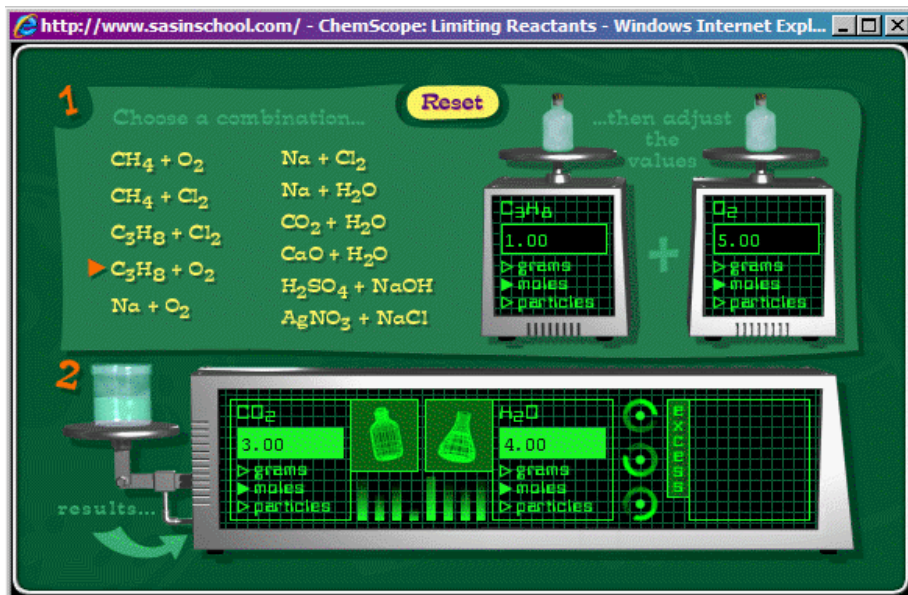


Figure 4. Screen shot of the module 10 chemscope interactivity

Prior to the administration of the module or instruction, the students were given a pretest (appendix A). The experimental group then used the online SIS module and the control groups received traditional instruction consisting of 1 hour of lecture and thirty minutes of hands on activity. The students were then given post test 1 which was identical to the pretest (appendix A). Students then completed an additional class of instruction and were given a second identical post test (appendix A).

### Setting of the study

The study took place over a six week period during a traditional school semester, which started in January and ended in June. The semester consisted of two quarters of nine weeks each. Each semester culminated in an End of Course test in Chemistry. Each class was on the block schedule and lasted ninety-minutes. The classroom used was an academic level classroom. North Carolina participates in a tracking system with the following tracks: Special Needs Self Contained, Special Needs Occupational Course of Study, College Technical Preparation, College / University Academic Course of Study, College / University Honors Course of Study and Advanced Placement / International

Baccalaureate Course of Study. As can be seen the academic level classes are geared towards average level students. Students were divided into groups of four, with each group using one computer during the course.

Teacher 1 in the study has a Bachelors degree in Biochemistry and was an alternative licensure teacher. Teacher 1 has been teaching for a total of four years.; three of which he has taught Physical Science and the other, Chemistry.

Teacher 2 in the study is an education specialist in Chemistry and was licensed in a traditional licensure program. Teacher 2 has been teaching for 23 years; 15 of which has been in chemistry.

### **Sample**

The population selected for this study was 117 students at a high school in North Carolina who met the following academic requirements; completed biology with a grade of C (76) or better and a Biology End Of Course Test Score of 3 (proficient) or better, completed Algebra I with a grade of C (76) or better and an Algebra I End Of Course Test Score of 3 (proficient) or better. In addition, the student was required to be enrolling in Algebra II and be on the four year (college) track.

Two chemistry classes participated in the study. Teacher 1 was responsible for 3 of the five classes, and Teacher 2 was responsible for the remaining 2 classes.

The population consisted of students of varied ethnicities and socioeconomic statuses. Table 1 outlines the demographic makeup of the whole school and the classes that participated in the study.

Table 1. Demographic make up of the school and class.

| Category                     | Percentage of School Population | Percentage of the Class |
|------------------------------|---------------------------------|-------------------------|
| American Indian              | 0.3                             | 0.8                     |
| Asian                        | 0.7                             | 0.8                     |
| Latino                       | 10.8                            | 9.1                     |
| African American             | 47.8                            | 32.9                    |
| Caucasian                    | 37.9                            | 54.7                    |
| Multiracial                  | 2.5                             | 1.7                     |
| Male                         | 52                              | 38.5                    |
| Female                       | 48                              | 61.5                    |
| Free and Reduced Lunch       | 34.4                            | 18.3                    |
| English as a Second Language | 2.8                             | 5.1                     |
| Limited English Proficiency  | 5.9                             | 0.9                     |

**Data collection, instrumentation and research design**

Data collection was accomplished with three tools: a unit pretest (appendix A), a post test (appendix A) given after each intervention, and an attitudinal journal. (appendix B). The pretest consisted of five multiple choice questions and five free response questions all tied to the NCSCOS. Each question tested the students' understanding of the topics taught during either instruction or the modules. The questions were 50% conceptual and 50% computational in nature. Students were instructed to leave blank any questions they could not answer. Each blank answer was counted as incorrect. The post test administered was the same as the pretest. Validity of the test was established through analysis by three experts qualified to teach chemistry. Their feedback was used to correct and further develop the test. The primary means used by the teachers was to align the questions with the course to the NCSCOS for Chemistry and the topics specifically used by the teacher in the SIS intervention.

During use of the module, the researcher informally noted student engagement. Student engagement was observed through recording on-task behavior. The final part of data collection was accomplished using a journal (appendix B), in which the students were asked to self-assess their level of learning using SIS, explain their likes and dislikes and give their overall opinion of the module or instruction. Students were given several prompts and allowed to answer the questions in a free response journal.

Two chemistry teachers agreed to participate in the study. Classes were assigned to either a control group or an experimental group for each teacher. Teacher 1 had one control group of 23 students and an experimental group of 43 students. Teacher 2 had one control group consisting of 27 students and an experimental group of 24 students.

Table 2 shows an in-depth timeline of the SIS study. The study was conducted over twenty-nine days. Each test was collected during the period in which it was given. The tests were scored out of ten total points, where one point was given for each correct answer.

Journal prompts were given to the students and students were allowed to keep the journal throughout the study and update it as often as they saw fit. The students were reminded to make notes about each module throughout the study. The journals were collected at the end of the study.



Table 2. Timeline of the SIS Study

| Day     | Experimental Group              | Control Group           | Time (Min)       |
|---------|---------------------------------|-------------------------|------------------|
| 1       | Pretest Module 692              | Pretest Module 692      | Up to 90         |
| 2       | Complete Module 692             | Traditional Instruction | 90               |
| 3       | Post Test Module 692            | Post Test Module 692    | Up to 90         |
| 4       | Journal Prompts (Take Home)     | None                    | End of the Study |
| 4 – 10  | Non reviewed content            | Non reviewed content    | 540              |
| 11      | Pretest Module 867              | Pretest Module 867      | Up to 90         |
| 12      | Traditional Instruction         | Tradition Instruction   | 90               |
| 13      | Traditional Instruction         | Traditional Instruction | 90               |
| 14      | Post Test I Module 867          | Post Test I Module 867  | Up to 90         |
| 15      | Complete Module 867             | Additional Instruction  | 90               |
| 16      | Post Test II Module 867         | Post Test II Module 867 | 90               |
| 17      | Journal Entry (Take Home)       | None                    | End of the Study |
| 17 -20  | Non reviewed content            | Non reviewed content    | 180              |
| 21      | Pretest Module 10               | Pretest Module 10       | Up to 90         |
| 22      | Complete Module 10              | Traditional Instruction | 90               |
| 23      | Post Test I                     | Post Test I             | Up To 90         |
| 24      | Traditional Instruction         | Traditional Instruction | 90               |
| 25      | Post Test II                    | Post Test II            | Up To 90         |
| 26      | Journal Entry                   | None                    | End of Study     |
| 27 - 29 | Final Journal Entries Collected | None                    | Study Complete   |

Table 3 shows the experimental design and a description of the treatments for each group. The experimental design is modeled after a Latin Square design.

Table 3. Experimental Design

| Teacher | Group        | n  | Module 692   | Module 867              | Module 10               |
|---------|--------------|----|--------------|-------------------------|-------------------------|
| 1       | Experimental | 43 | PrT – M - PT | PrT – I - PT1 – M – PT2 | PrT – M – PT1 – I PT2   |
| 1       | Control      | 23 | PrT – I – PT | PrT – I – PT1 – I – PT2 | PrT - I – PT1 – I – PT2 |
| 2       | Experimental | 24 | PrT – M - PT | PrT – I - PT1 – M – PT2 | PrT – M – PT1 – I PT2   |
| 2       | Control      | 27 | PrT – I – PT | PrT – I – PT1 – I – PT2 | PrT - I – PT1 – I – PT2 |

Note. Pretest (PrT), Module (M), Post Test (PT), Traditional Instruction (I)

**Data analysis**

Student test results were recorded into an Excel spreadsheet by group, by teacher and by module. The scores were analyzed using a paired two sample t-test to look at significant differences between means for each class and each teacher. The control group tests and the experimental groups tests were then analyzed using a paired two sample t-test to test for a significant difference between the means of each group. The mean,

standard deviations, p-values and t-stats were calculated and recorded. Student grades were computed and placed in a scatter plot by group to show differences and trends arising within the data sets.

Qualitative data was collected via student journals. Students were asked to complete questions regarding the module throughout each section of the study. Journals were collected at the end of the study and reviewed for common trends in student responses. Trends were summarized and discussed. In addition, informal observations of student discussion and interactions were noted.

#### Chapter IV Results

This chapter outlines the significant results of the study. The results show a significant statistical difference between traditional instruction and the use of computer instruction through the application of a t-test. The results also show that computer instruction is superior to traditional instruction.

Table 4 shows the mean, standard deviation, p-value and t-stat of the pretest for each module. Table 5 shows the mean, standard deviation, p-value and t-stat for post test I for each module. Table 6 shows the mean and standard deviation for post test II for each module.

Table 4. Means, standard deviations, p-values and t-tests for the pretest

| Teacher | Group | n  | Module | Mean | SD   | p-value  | t-stat |
|---------|-------|----|--------|------|------|----------|--------|
| 1       | Exp   | 43 | 692    | 0.40 | 0.82 | < 0.0001 | -14.50 |
| 1       | Ctrl  | 23 | X      | 0.43 | 0.66 | < 0.0001 | -6.70  |
| 2       | Exp   | 24 | 692    | 0.21 | 0.66 | < 0.0001 | -6.60  |
| 2       | Ctrl  | 27 | X      | 0.56 | 0.88 | < 0.0001 | -9.70  |
| 1       | Exp   | 43 | 867    | 1.02 | 1.00 | < 0.0001 | -8.29  |
| 1       | Ctrl  | 23 | X      | 1.13 | 1.03 | < 0.0001 | -6.82  |
| 2       | Exp   | 24 | 867    | 2.32 | 1.57 | < 0.0001 | -5.55  |
| 2       | Ctrl  | 27 | X      | 1.85 | 2.15 | < 0.0001 | -6.55  |
| 1       | Exp   | 43 | 10     | 1.21 | 1.05 | < 0.0001 | -9.81  |
| 1       | Ctrl  | 23 | X      | 0.65 | 0.57 | < 0.0001 | -9.23  |
| 2       | Exp   | 24 | 10     | 1.04 | 0.77 | < 0.0001 | -10.56 |
| 2       | Ctrl  | 27 | X      | 0.62 | 0.70 | < 0.0001 | -7.24  |

*Note.* p-values and t-stat are for the comparison between the pretest and post test I for each module within each group.

Table 5. Means, standard deviations, p-values and t-tests for post test I

| Teacher | Group | n  | Module | Mean | SD   | p-value  | t-stat |
|---------|-------|----|--------|------|------|----------|--------|
| 1       | Exp   | 43 | 692    | 4.53 | 1.9  | X        | X      |
| 1       | Ctrl  | 23 | X      | 2.96 | 1.9  | X        | X      |
| 2       | Exp   | 24 | 692    | 4.93 | 2.0  | X        | X      |
| 2       | Ctrl  | 27 | X      | 3.21 | 1.9  | X        | X      |
| 1       | Exp   | 43 | 867    | 3.17 | 1.48 | < 0.0001 | -7.00  |
| 1       | Ctrl  | 23 | X      | 3.75 | 2.09 | < 0.0001 | -6.00  |
| 2       | Exp   | 24 | 867    | 4.24 | 2.07 | < 0.0001 | -8.49  |
| 2       | Ctrl  | 27 | X      | 3.88 | 2.14 | < 0.0001 | -5.19  |
| 1       | Exp   | 43 | 10     | 3.55 | 1.48 | 0.0140   | -2.55  |
| 1       | Ctrl  | 23 | X      | 2.73 | 0.57 | 0.0205   | -2.39  |
| 2       | Exp   | 24 | 10     | 3.92 | 1.38 | 0.0370   | -2.06  |
| 2       | Ctrl  | 27 | X      | 2.07 | 0.69 | 0.0008   | -2.06  |

*Note.* p-values and t-stat are for the comparison between the post test I and post test II for each module within each group.

Table 6. Means and standard deviations for post test II

| Teacher | Group | n  | Module | Mean | SD   |
|---------|-------|----|--------|------|------|
| 1       | Exp   | 43 | 692    | X    | X    |
| 1       | Ctrl  | 23 | X      | X    | X    |
| 2       | Exp   | 24 | 692    | X    | X    |
| 2       | Ctrl  | 27 | X      | X    | X    |
| 1       | Exp   | 43 | 867    | 5.80 | 1.77 |
| 1       | Ctrl  | 23 | X      | 5.07 | 2.18 |
| 2       | Exp   | 24 | 867    | 5.72 | 2.05 |
| 2       | Ctrl  | 27 | X      | 5.11 | 1.84 |
| 1       | Exp   | 43 | 10     | 3.90 | 1.56 |
| 1       | Ctrl  | 23 | X      | 3.13 | 1.01 |
| 2       | Exp   | 24 | 10     | 4.44 | 2.02 |
| 2       | Ctrl  | 27 | X      | 2.96 | 1.00 |

*Note:* The control group did not use the SIS modules.

The teacher 1 experimental group pretest mean for module 692 is 0.395 and the post test mean for the same group is 4.53. A Paired Two Sample t-test was conducted to explore the hypothesis that there is a difference in the means from the pre to post test. The test was significant  $t(43)=-14.50, p<0.05$ . The teacher 1 control group pretest mean for module 692 is 0.435 and the post test mean for the same group is 2.96. A Paired Two Sample t-test was conducted to explore the hypothesis that there is a difference in the means from the pre to post test. The test was significant  $t(23)=-6.70, p<0.05$ . For both groups the mean score for the student pretest and post test was significantly different.

The teacher 2 experimental group pretest mean for module 692 is 0.208 and the post test mean for the same group is 3.20. A Paired Two Sample t-test was conducted to explore the hypothesis that there is a difference in the means from the pre to post test. The test was significant  $t(24)=-6.60, p<0.05$ . The teacher 2 control group pretest mean for module 692 is 0.556 and the post test mean for the same group is 4.92. A Paired Two Sample t-test was conducted to explore the hypothesis that there is a difference in the

means from the pre to post test. The test was significant  $t(27)=-9.71$ ,  $p<0.05$ . For both groups the mean score for the student pretest and post test was significantly different.

The teacher 1 experimental group pretest mean for module 867 is 1.02 the post test I mean for the group is 3.17 and the post test II mean is 5.07. Two, Paired Two Sample t-tests were conducted to explore the hypothesis that there is a difference in the means from the pretest to post test I and from post test I to post test II. The first test was significant  $t(43)=-8.29$ ,  $p<0.05$ . The second test also showed that the means for post test I and post test II was also different  $t(43)=-7.00$ ,  $p<0.05$ . The teacher 1 control group pretest mean for module 867 is 1.125, the post test I mean for the same group is 3.75 and the post test II mean is 5.08. Two, Paired Two Sample t-tests were conducted to explore the hypothesis that there is a difference in the means from the pretest to post test I and from post test I to post test II. The first test was significant  $t(23)=-6.83$ ,  $p<0.05$ . The second test also showed that the means for post test I and post test II were also different  $t(23)=-5.99$ ,  $p<0.05$ . For both groups the mean scores were significantly different.

The teacher 2 experimental group pretest mean for module 867 is 2.32 the post test I mean for the group is 4.24 and the post test II mean is 5.72. Two, Paired Two Sample t-tests were conducted to explore the hypothesis that there is a difference in the means from the pretest to post test I and from post test I to post test II. The first test was significant  $t(24)=-5.55$ ,  $p<0.05$ . The second test also showed that the means for post test I and post test II was also different  $t(24)=-8.49$ ,  $p<0.05$ . The teacher 2 control group pretest mean for module 867 is 1.846, the post test I mean for the same group is 3.884 and the post test II mean is 5.115.

Two, Paired Two Sample t-tests were conducted to explore the hypothesis that there is a difference in the means from the pretest to post test I and from post test I to post test II. The first test was significant  $t(27)=-6.54$ ,  $p<0.05$ . The second test also showed that the means for post test I and post test II were also different  $t(27)=-5.19$ ,  $p<0.05$ . For both groups the mean scores were significantly different.

The teacher 1 experimental group pretest mean for module 10 is 1.21 the post test I mean for the group is 3.54 and the post test II mean is 3.90. Two, Paired Two Sample t-tests were conducted to explore the hypothesis that there is a difference in the means from the pretest to post test I and from post test I to post test II. The first test was significant  $t(43)= 2.08$ ,  $p<0.05$ . The second test also showed that the means for post test I and post test II was also different  $t(43)=-2.56$ ,  $p<0.05$ . The teacher 1 control group pretest mean for module 10 is 0.652, the post test I mean for the same group is 2.739 and the post test II mean is 3.130. Two, Paired Two Sample t-tests were conducted to explore the hypothesis that there is a difference in the means from the pretest to post test I and from post test I to post test II. The first test was significant  $t(23)=-9.24$ ,  $p<0.05$ . The second test also showed that the means for post test I and post test II were also different  $t(23)=-2.40$ ,  $p<0.05$ . For both groups the mean scores were significantly different.

The teacher 2 experimental group pretest mean for module 10 is 1.04 the post test I mean for the group is 3.92 and the post test II mean is 4.44 Two, Paired Two Sample t-tests were conducted to explore the hypothesis that there is a difference in the means from the pretest to post test I and from post test I to post test II. The first test was significant  $t(24)=-10.56$ ,  $p<0.05$ . The second test also showed that the means for post test

I and post test II was also different  $t(24)=-2.06, p<0.05$  The teacher 2control group pretest mean for module 10 is 0.615, the post test I mean for the same group is 2.08 and the post test II mean is 2.96. Two, Paired Two Sample t-tests were conducted to explore the hypothesis that there is a difference in the means from the pretest to post test I and from post test I to post test II. The first test was significant  $t(27)=-7.24, p<0.05$ . The second test also showed that the means for post test I and post test II were also different  $t(27)=-3.83, p<0.05$ . For both groups the mean scores were significantly different.

Figures 5, 6 and 7 show a graphical comparison of the pretest; post test I and post test II for each module. The figure shows that the mean score for each class increased as much or more than traditional instruction after using the module. Therefore, the original hypothesis is supported; students who use SIS increase their understanding of content more than traditional instruction.

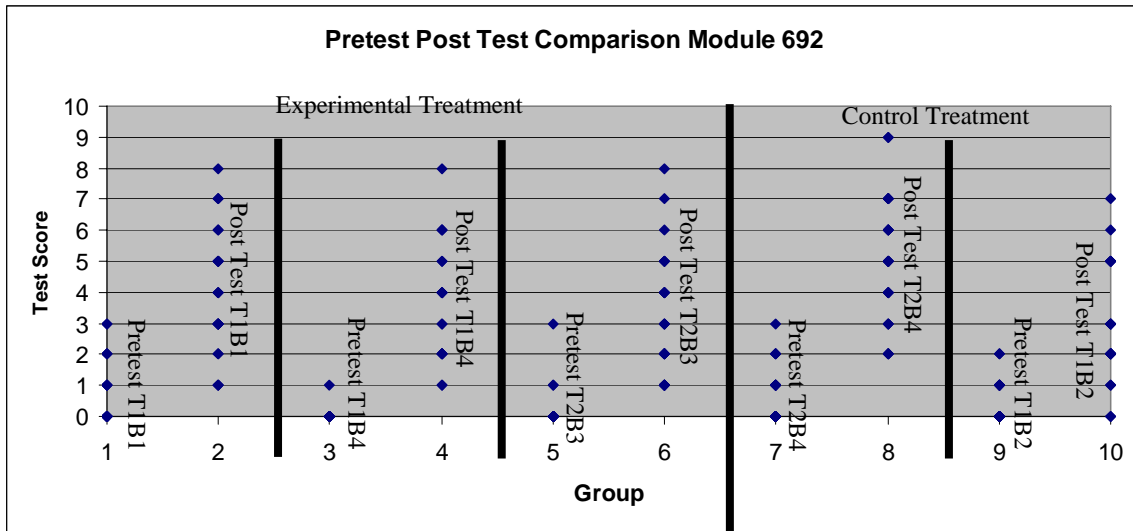


Figure 5. Comparison of pretest and post test results for module 692

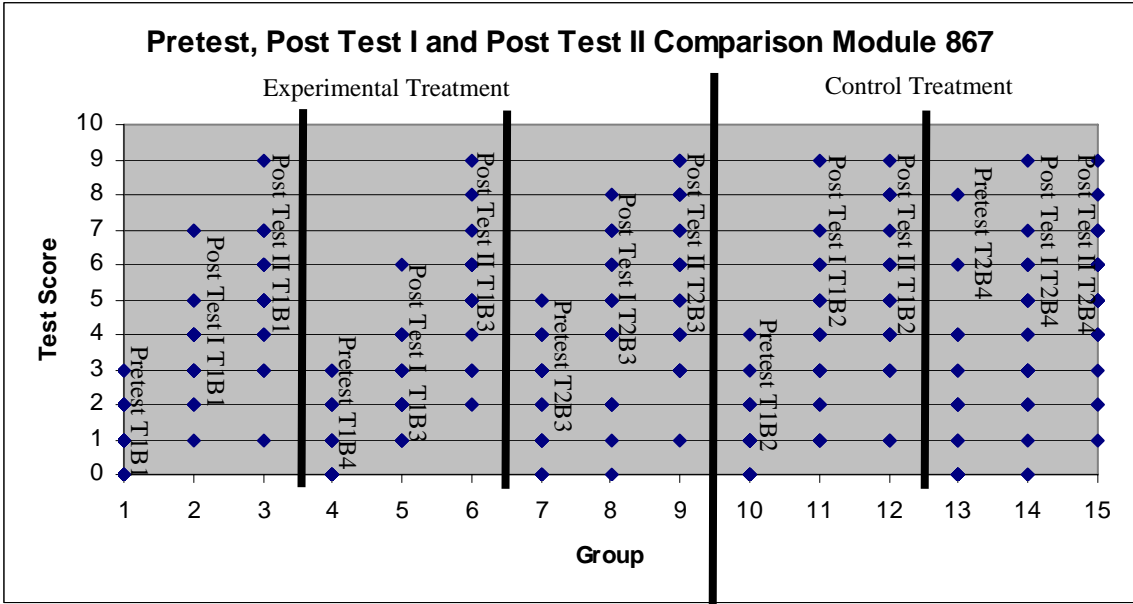


Figure 6. Comparison of pretest, post test I and post test II for module 867

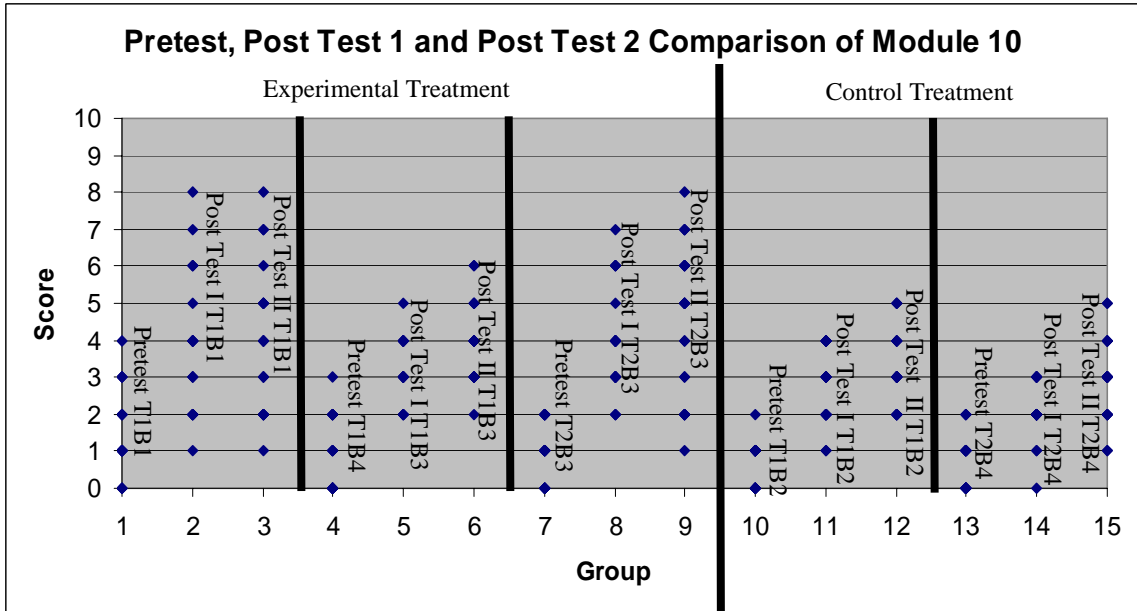


Figure 7. Comparison of pretest, post test I and post test II for module 10.



Table 7 shows the results of the comparison of the control group to the experimental group. A paired two sample t-test on each test and module was conducted to determine if there is a significant difference between the control group and the experimental group. It should be noted that the teacher 1 pretest comparison for module 10 showed that there were some improvements based on the p-value, however the improvements failed to show significant difference in the means as shown by the t-stat.

The pretests for all of the modules showed no significant difference between the experimental group and the control group. Post Test one for module 692 and module 10 showed significant differences between the experimental group and the control group. Module 867 showed no significant difference between the control and experimental groups. Post test II showed significant difference between the experimental group and control group for module 867. Teacher 2 showed significant difference for post test II between the control and experimental groups, while teacher 1 showed no significant difference.

Table 7. Comparison of control group to experimental group test results

| Teacher | Module | Prt E vs. Prt C |        |             | Pt I E vs. Pt I C |        |             | Pt II E Vs. Pt II C |        |      |
|---------|--------|-----------------|--------|-------------|-------------------|--------|-------------|---------------------|--------|------|
|         |        | p-value         | t-stat | Significant | p-value           | t-stat | Significant | p-value             | t-stat | Sig. |
| 1       | 692    | 0.840           | 1.99   | No          | 0.002             | 3.17   | Yes         | X                   | X      | X    |
| 2       | 692    | 0.056           | 1.67   | No          | 0.004             | -3.05  | Yes         | X                   | X      | X    |
| 1       | 867    | 0.697           | -0.39  | No          | 0.190             | -1.32  | No          | 0.040               | 2.00   | Yes  |
| 2       | 867    | 0.375           | 1.94   | No          | 0.550             | 1.93   | No          | 0.043               | 2.01   | Yes  |
| 1       | 10     | 0.010           | 1.67   | No          | 0.023             | 2.00   | Yes         | 0.040               | 1.97   | No   |
| 2       | 10     | 0.060           | 1.67   | No          | 0.002             | 2.01   | Yes         | 0.002               | 2.01   | Yes  |

The three common factors found during review of the student journals were: comfort with computer use, the impact of information available, and the novelty of the use of computer simulations in class as compared to differences from traditional instruction. Three of the 117 students did not want to complete the journal entries

associated with the study. The three students however did complete all of the instruction, module use and pre and post tests.

*Factor One: Comfort with computer use*

Of the 114 respondents in the journal only two students indicated that they were not comfortable using the computer. The respondents who indicated they were comfortable with the computer stated that they use the computer and the Internet almost, if not every, day.

The two students who rated themselves uncomfortable with computer use indicated that they did not have Internet access at home and that they tended not to use computers at the school very often.

Computer familiarity can impact student achievements by causing the students to disengage from the module and work to increase their comfort levels with the computer. This can cause a distraction from the learning that should be taking place. Teachers should work to increase computer familiarity for the students by doing introductory modules and basic internet use procedures prior to instruction.

*Factor Two: Impact of information availability*

100 of the 114 students indicated that the amount of information available on the SIS site was vast. However, there was varying opinion on the value of the amount of information. Students indicated that the amount of information available to the students made the module significantly more difficult to complete.

When the amount of information is beyond a threshold level students become overwhelmed with attempting sort through and find meaning in the large amounts of data. This can lead to disengagement.

*Factor Three: Differences from traditional instruction*

All of the responding students did comment on the novelty of the use of the computers in the science class. As a result the third factor that became apparent during the journal responses was that the students agreed that the use of the site in class was different than anything they had previously taken part in.

The Hawthorn effect can cause students to initially take more interest in the topic than traditional modes of instruction. This high level of initial engage in the computer modules can lead initial success for the students.. As the students continue to use the modules in class, the engagement will decrease as a result of over-familiarity with this mode of instuction. This will cause a slow decline in the student achievement. By interspersing the modules throughout the unit and semester the teachers can maintain high levels of engagement and thus help to maintain achievement levels.

Chapter V  
Discussion

**Treatment analysis**

The results of the study support the original hypothesis. The mean differences for the pretest between the control and experimental groups were not significantly different. The teacher 1 module 10 pretest does show that there is some difference between the control and treatment groups, however the mean difference is not significant.

This undefined difference may be due to individual student variations between the control and treatment class.

The largest difference for teacher 1 was noted in module 10 with a mean difference of 0.56 points. The largest mean difference for teacher 2 is in module 867 with a difference of 0.47 points. This shows that the control and experimental classes have a similar level of prior knowledge.

The results for the post test for module 692 show that students in teacher 1's class who used the Curriculum Pathways module scored a class average 1.57 points higher than students in teacher 1's class who were instructed using traditional teaching methods. The results for module 692 showed that students in teacher 2's class who used the curriculum pathways module scored a class average of 1.72 points higher than those students who received traditional instruction. This indicates that Curriculum Pathways is superior to traditional drill and practice when teaching the concepts associated with chemical quantities.

The results for post test I for module 867 show that there was no significant difference between the level of instruction for each class. This caused each group's mean to improve by approximately the same amount. The mean difference for the control and experimental group for teacher 1 is 0.58 points while the mean difference for the control and experimental group for teacher 2 is 0.36. In both cases the mean difference was not significant. Post test I for module 867 was given after a period of instruction of 90 minutes by the teacher. Since the mean difference between the two groups was not significantly different, the amount of growth for the control group and experimental

group was statistically the same as a result of the period of instruction by the teacher.

This shows that both classes were at the still at the same achievement level prior to the administration of each treatment.

The results for post test II for module 867 shows that there is a significant difference in the amount growth in the means for the experimental and control group. The mean for the experimental group (SAS module) with teacher 1 is 0.83 points higher than the mean for the control group (traditional instruction). Teacher 2 showed similar results with the experimental group scoring 1.21 points higher than the control group. This supports the hypothesis that the use of SIS improves student understanding of the chemistry mole and further support the assertion that computer instruction used as an adjunct to regular instruction is superior to regular instruction alone. This result also indicates that the modules may be used by the teacher to remediate students.

The results for post test I module 10 shows that the class mean difference between the experimental and control groups for teacher 1 is 0.82 points. The mean class difference between the experimental (SAS module) and control groups (traditional instruction) for teacher 2 is 1.85 points. This indicates that Curriculum Pathways can be used to build foundational knowledge prior to a period of traditional instruction. This can aid teachers in increasing the level of prior knowledge about topics before a period of formal instruction.

The results for post test II are mixed. Teacher 1 shows no significant difference between the control and experimental group. Teacher 2, however, does show a significant difference between the control and experimental groups with a mean difference of 1.48

points. The difference in experience levels may have allowed teacher 2 to expand and incorporate the module's material in a more substantial way. This may have resulted in significant growth, whereas teacher 1 may not have expanded much beyond the module. This resulted in teacher 1's students showing little growth however this growth was not considered statistically significant. This shows that teachers should carefully consider the content of the module and instruction and ensure that each one not only complements but also expands upon the other.

Table 8 shows the comparison of the mean difference between the experimental and control group's pretest, post test I and post test II. The table also indicates whether or not the difference was significant.

Table 8. Mean difference and significance of the pretest, post test I and post test II

| Teacher | Module | Mean Difference E vs. C Pt / Significant | Mean Difference E vs. C PT I / Significant | Mean Difference E vs. C PT II / Significant |
|---------|--------|--|--|---|
| 1       | 692    | 0.03 / No                                | 1.57 / Yes                                 | X   |
| 2       | 692    | 0.35 / No                                | 1.72 / Yes                                 | X   |
| 1       | 897    | 0.11 / No                                | 0.58 / No                                  | 0.83 / Yes                                  |
| 2       | 897    | 0.47 / No                                | 0.36 / No                                  | 1.21 / Yes                                  |
| 1       | 10     | 0.56 / No                                | 0.82 / Yes                                 | 0.77 / No                                   |
| 2       | 10     | 0.81 / No                                | 1.85 / Yes                                 | 1.48 / Yes                                  |

**By treatment analysis**

The lack of a significant difference in the pretest scores for all modules shows no one group of students carried more prior knowledge than another. Thus all students worked from the same amount of prior knowledge concerning each topic covered by the module.

The module 692 post-test shows a significant difference in the mean between the experimental mean and the control mean. This result shows that the students in the class with teacher 1 in the experimental group using the module grew a total of 15.7% more than the student who did not use the module. Teachers 2's experimental group grew a total of 17.2% more than the students who did not use the module. Significant growth was achieved regardless of the amount of experience each teacher has. This shows that the module is more effective in increasing content knowledge than a traditional style of instruction.

The module 897 post-test I shows no significant difference between the experimental and control group. However, each group grew, with teacher 1's group showing a 5.8% difference between traditional instruction and teacher 2's group showing a 3.6% difference for traditional instruction. With no significant difference between the control group and the experimental group it is suggested that each class continued to grow at the same rate and was affected the same way through teacher instruction. Post-test II for module 897 shows an 8.3% difference for teacher 1 and a 12.1 % difference for teacher 2. The difference between the two tests for teacher 1 was 2.5% with the experimental group showing the most increase.

Module 10 post test I shows a 8.2% difference in the students score between the experimental and control scores for teacher 1 and a 18.5% difference in the students score for teacher 2. Both teachers showed an increase in student scores for both groups, however, the experimental group showed the greatest increase. Post-test II shows a difference of 7.7% between the control and experimental group. Teacher 1 showed no

significant difference between the experimental and control groups. Teacher 2 showed a significant increase between the experimental and control group. The continued increase in student scores by teacher 2's class may be as a result of the level of experience.

With the large amount of experience teacher two possesses, teacher two may have more successfully incorporated the modules into his teaching methodologies. The higher success rate of teacher 2 in almost all of the modules could be due to this teacher's higher experience level. Teacher 2 has 15 years of experience teaching chemistry and is more successful in teaching chemistry and integrating the material from the modules. This may be due to teacher 2's ability to focus more exclusively on the pedagogy associated with the chemistry course.

The student journals indicated that three factors played into how the students scored on the test. The first common factor of comfort with the computer did not seem to be an issue, as only two of the students indicated any problems centered on mechanics of using the site or the computer. Thus, ability to use the computer or the site did not play into the student's ability to score well on the post test.

Another common factor found in the student journal was novelty of using the SIS program in the classroom. A large number of the students had a positive attitude about the use of SIS in the classroom. Thus the mode of instruction was positive and seemed to help.

The final factor to be discussed is the amount of information available to the students. Of the three common factors found during the journal, this factor is what seems to be the differentiating one when it comes to student scores. All of the students said that



the amount of information available was far more than previously given to them on a specific topic.

The students who made the greatest increase in scores did not mention the amount of available information as a problem and discussed it as a positive. Students who did not increase their scores very much if at all tended to see the amount of information as a negative quality. They stated that the amount of information available to them was confusing. This, coupled with an already complex topic, seems to be the item responsible for the students' minimal increase in their post test score.

Further areas which should be addressed are how the SIS modules affect student scoring across gender, race and socioeconomic status. A second area of study is a review of SIS affect on content retention after significant periods of time.

### **Implication for Practice**

Student seating arrangements played a role in the student's ability to process the information available in Curriculum Pathways. During the study students were clustered around a computer in a four to one ratio. While completing the modules students were observed to work together to answer and discuss questions during the module. This was an unexpected outcome based on infrastructure limitations within the classroom.

Newer teachers (those with less than 5 years of teaching experience) show benefits of increased practice and reliable information for their students at a time when the teacher's course content is still being developed. Experienced teachers (those with over 5 years of teaching experience) benefit from further student practice and novel content presentation, which results increasing student engagement. Additionally, more

experienced teachers may be more able to integrate the module content more effectively as demonstrated in module 10 by teacher 2. These findings support the findings of Kozma 1994 and Thornburg 1999.

The most effective use of Curriculum Pathways occurred when the teacher provided foundational knowledge and then used the modules as a means to reinforce instruction. This practice allows students to use prior knowledge when negotiating meaning from the modules.

Preservice educators should become familiar with technology integration in the classroom prior to student teaching. This should be taught along with traditional methodologies. Additionally, the preservice educators should have a good understanding of the hardware and software configurations needed to effectively implement technology in the classroom. This will allow them to more effectively design and setup technology-rich environments within their classroom. Furthermore, the preservice educator will then have the ability to more successfully anticipate questions and resolve problems from students while using the technology.

This study also supports the use of professional development to instruct inservice teachers on the correct use of technology. Teachers who are more familiar with technology are far more likely to use it and do so effectively in conjunction with traditional instruction (Kozma 1994).

### **Implication for Technology**

The study supports the assertions in the literature that the use of online simulations does help to increase student understanding of chemistry concepts. Wu and

Shah (2004) suggest the use of the computers and models allows students to visualize chemistry by providing multiple representations and descriptions (Wu & Shah 2004).

By successfully visualizing chemistry through multiple representations, students are able to link their constructs to that of the content. SIS accomplished this through representation of the interactive nature of chemistry through “Chemscope” simulations. SIS also allowed students to move between a traditional 2D representation of chemistry and 3D representations of chemical equations through the use of chemical modeling. The three modules also reduced cognitive load by making information more explicit and integrated within the students classroom work.

Computer simulation aids in the promotion of understanding of concepts through manipulations on the computer not otherwise available to students when taught in the traditional methodology. This study further supports the SAS assertion that the development of a learner centered education system with technology use as an adjunct significantly increases the achievement of students in the classroom. The study also supports the assertion put forth in the technological approach to education in the Pipes and Wilson 1996 study, which states that the use of computer models can be used to increase student achievement and understanding of conceptually difficult ideas.

This study shows that there is potential in the use of online simulations to help students develop their understanding of chemistry. Some areas of further study are the use of multiple models and their effects on learners understanding of multiple chemistry topics. SIS in schools is only intended as an adjunct to regular instruction and should not be used as a replacement for classroom instruction facilitated by the teacher. The findings

in this study support the idea that technology can be useful for helping to increase students understanding of topics.

Further studies may address the question: Does reducing the information load from the SIS website allow students to score better in a pre and post test situation? A secondary question that may be addressed is: Does student collaboration while using the SIS site allow for better understanding? In addition, an area to be further explored is the effect of group negotiation of understanding and how online simulation stimulates this negotiation and engagement of the group as a whole.

School design and technology resource allocation should change to provide support to those teachers who use technology. For example, the classroom in which the study took place was designed to support only eight computers. Classrooms need to be redesigned or refit to accommodate technology use. As a result of the provided infrastructure, students had to share resources. A decrease in the computer to student ratio from four to one to one computer per student would greatly aid in module completion, and allow the students to process information that may otherwise be rushed due to peer influence. Students could then run a simulation multiple times and work through items which might be missed while working in groups.

Administration within the school also needs to recognize the significant role that technology does and will play in the classroom. The administration can more effectively design hiring criteria to better assess the level of technology use and understanding by the inservice teachers and potential hires. This can lead to more effective utilization of technology.

In summary, technology shows superior outcomes to traditional instruction. With the proper policy and preservice and inservice training, technologically rich environments can be effectively designed and used in the classroom.

## References

- Byron, R. & Wilson, J. (1996). A multimedia model for undergraduate education. *Technology in Society*, 18( 3), 387-401.
- Clark, R. (1994). Media will never influence learning. *Educational Technology Research and Development*, 42(2), 21–29.
- Dossey, J, McCrone, S & C Gonzales, Trends in international mathematics and science study (TIMSS) U.S. Department of Education, Institute of Educational Science
- Bill and Melinda Gates Foundation. (2000). *Research on Computers and Education: Past, present, and future*, Retrieved October 20, 2007, from <http://instruction.nsd.org/vision/docs/ComputerResearchSummary.pdf>
- Bayraktar, S. (2001) A meta analysis of the effectiveness of computer-assisted instruction in science education. *Journal of Research of Technology in Education*, 34(2)
- Flinn,M., & Gravatt, B. (1995). The efficacy of computer assisted instruction: A meta-analysis. *Journal of Educational Computing Research*, 12(5), 219-242.
- Garrison, D. R., and Shale, D. (1990). A new framework and perspective, *Education at a distance: From Issues to Practice*: 21(4), 123-133.
- Geban, O, Askar, P and Ozkan, I. (1992).Effect of computer simulations and problem-solving approaches on high school students. *Journal of Educational Research*, 86(1), 5-10

- Gilbert, J. K., and Boutler, C. (Eds.) (2000). *Developing Models in Science Education*, Kluwer Academic Publishers: Dordrecht, The Netherlands.
- Johnstone, A. H. (1993). The development of chemistry teaching: a changing response to changing demand. *Journal of Chemical Education* 70, 701–705
- Kozma, R. (1994). Will media influence learning. Reframing the debate. *Educational Technology Research & Development*, 42(2), 7–19.
- Kulik, C , & Kulik, A. (1991). Effectiveness of computer-based instruction: An updated analysis. *Computers in Human Behavior*, 7(1), 75—94.
- Liao, C. (1998). Effects of hypermedia versus traditional instruction on students' achievement. *Journal of Research on Computing in Education*, 30(A),341-359.
- Milken Family Foundation. (1999) *Meta-Analytic studies of findings on computer based instruction. Technology assessment in education and training*. Retrieved October 20, 2007, from <http://www.mff.org/pubs/ME161.pdf>
- Milken Exchange on Education Technology (1999). *The Impact of Education Technology on Student Achievement*, Retrieved, June 03, 2007, from <http://www.milkenexchange.org>
- National Science Teachers Association. (2001). *Assessment Position Statement*. Retrieved October 20, 2007, from <http://www.nsta.org/159&psid=40>
- Nye, J (2004). *Soft Power: The Means to Success in World Politics*. New York: Public Affairs

- Pepin, Y. (1998). *Practical knowledge and school knowledge: a constructivist representation of education. Constructivism and Education: 173-192* Cambridge University Press.
- Presseisen, B. (1972). Piaget's conception of structure: implications for curriculum. Ed.D. Dissertation, Temple University
- Reeves, T.C. (1992) Evaluating interactive multimedia. *Educational Technology*, 32(5), 47-52
- SAS. (2004). The research basis for Curriculum Pathways from SAS in School: web based educational resources for grades 8-14 White paper. SAS, Cary, North Carolina
- Shuell, J., & Farber. L. (2001). Student perceptions of technology use in college courses. *Journal of Educational Computing Research*, 24, 119–138.
- Thornburg, D. D. (1999, December). Technology in K-12 education: Envisioning a new future. White paper commissioned for the Forum on Technology in Education: Envisioning the Future, Washington, DC.
- Windschitl, M. (2000). Supporting the development of science inquiry skills with special classes of software. *Educational Technology Research and Development* 48,81
- Wu, H. & Shah, P. (2004). Exploring visuospatial thinking in chemistry learning. *Science Education* 88,465–492.
- Xiufeng Liu. (2006) Effects of combined hands-on laboratory and computer modeling on student learning of gas laws: a quasi-experimental study. *Journal of Science Education and Technology*. 15( 1), 89-100



## Appendices

## Appendix A. Pretest and post test for modules

### SIS Study Test Chapter 10 Chemical Quantities Module 692

#### Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question.

- Which of the following is NOT a representative particle?
  - Atom
  - Cation
  - anion
  - all of the above
- How many moles of silver atoms are in  $1.8 \times 10^{20}$  atoms of silver?
  - $3.0 \times 10^{-4}$
  - $3.3 \times 10^{-3}$
  - $3.0 \times 10^{44}$
  - $1.1 \times 10^{44}$
- Which of the following gas samples would have the largest number of representative particles at STP?
  - 12.0 L He
  - 7.0 L O<sub>2</sub>
  - 0.10 L Xe
  - 0.007 L SO<sub>3</sub>
- Which expression represents the percent by mass of nitrogen in NH<sub>4</sub>NO<sub>3</sub>?
  - $14 \text{ g N}/80 \text{ g NH}_4\text{NO}_3 \times 100\%$
  - $28 \text{ g N}/80 \text{ g NH}_4\text{NO}_3 \times 100\%$
  - $80 \text{ g NH}_4\text{NO}_3/14 \text{ g N} \times 100\%$
  - $80 \text{ g NH}_4\text{NO}_3/28 \text{ g N} \times 100\%$
- Which of the following compounds has the lowest percent gold content by weight?
  - AuOH
  - Au(OH)<sub>3</sub>
  - AuCl<sub>3</sub>
  - AuI<sub>3</sub>

#### Short Answer

- How many representative particles are in 1.45 g of a molecular compound with a molar mass of 237 g?
- Find the mass in grams of  $3.10 \times 10^{23}$  molecules of F<sub>2</sub>.
- Find the mass, in grams, of  $1.40 \times 10^{23}$  molecules of N<sub>2</sub>.
- What is the percent composition of NiO, if a sample of NiO with a mass of 41.9 g contains 33.1 g Ni and 8.8 g O?
- Calculate the molecular formulas of the compounds having the following empirical formulas and molar masses: C<sub>2</sub>H<sub>5</sub>, 58 g/mol; CH, 78 g/mol; and HgCl, 236.1 g/mol.

## SIS Chapter 11 Test Chemical Reactions Module 867

### Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question.

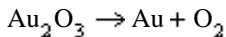
- Chemical reactions \_\_\_\_\_.
  - occur only in living organisms
  - create and destroy atoms
  - only occur outside living organisms
  - produce new substances
- Symbols used in equations, together with the explanations of the symbols, are shown below. Which set is correct?
  - (g), grams
  - (l), liters
  - (aq), dissolved in water
  - (s), solid product
- If you rewrite the following word equation as a balanced chemical equation, what will the coefficient and symbol for fluorine be?

nitrogen trifluoride  $\rightarrow$  nitrogen + fluorine

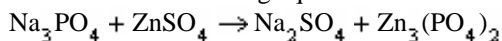
  - $6F_2$
  - $F_3$
  - $6F$
  - $3F_2$
- Which of the following statements is NOT true about double-replacement reactions?
  - The product may precipitate from solution.
  - The product may be a gas.
  - The product may be a molecular compound.
  - The reactant may be a solid metal.
- The equation  $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$  is an example of which type of reaction?
  - combination reaction
  - single-replacement reaction
  - decomposition reaction
  - double-replacement reaction

### Short Answer

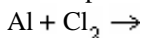
6. Balance the following equation.



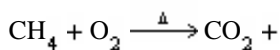
7. Balance the following equation.



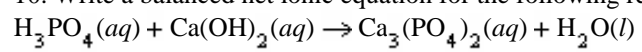
8. Complete and balance the following equation.



9. Complete and balance the following equation.



10. Write a balanced net ionic equation for the following reaction.



## SIS Study Test Chapter 12 Stoichiometry Module 10

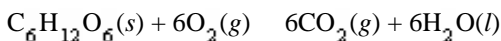
### Multiple Choice

Identify the letter of the choice that best completes the statement or answers the question.

1. In the reaction  $2\text{CO}(g) + \text{O}_2(g) \rightarrow 2\text{CO}_2(g)$ , what is the ratio of moles of oxygen used to moles of  $\text{CO}_2$  produced?

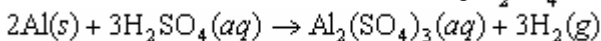
- a. 1:1  
b. 2:1  
c. 1:2  
d. 2:2

2. How many moles of glucose,  $\text{C}_6\text{H}_{12}\text{O}_6$ , can be "burned" biologically when 10.0 mol of oxygen is available?



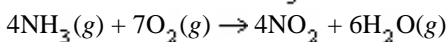
- a. 0.938 mol  
b. 1.67 mol  
c. 53.3 mol  
d. 60.0 mol

3. Aluminum reacts with sulfuric acid to produce aluminum sulfate and hydrogen gas. How many grams of aluminum sulfate would be formed if 250 g  $\text{H}_2\text{SO}_4$  completely reacted with aluminum?



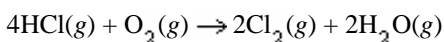
- a. 0.85 g  
b. 290 g  
c. 450 g  
d. 870 g

4. How many liters of  $\text{NH}_3$ , at STP, will react with 5.3 g  $\text{O}_2$  to form  $\text{NO}_2$  and water?



- a. 0.004 23 L  
b. 2.12 L  
c. 3.03 L  
d. 6.49 L

5. How many liters of chlorine gas can be produced when 0.98 L of  $\text{HCl}$  react with excess  $\text{O}_2$  at STP?



- a. 0.98 L  
b. 0.49 L  
c. 3.9 L  
d. 2.0 L

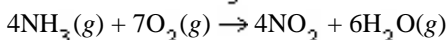
### Short Answer

6. If a tricycle factory ordered 33,432 wheels in 2002 and used all of them, how many tricycles did the factory produce?

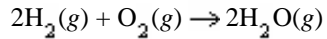
7. If a total of 13.5 mol of  $\text{NaHCO}_3$  and 4.5 mol of  $\text{C}_6\text{H}_8\text{O}_7$  react, how many moles of  $\text{CO}_2$  and  $\text{Na}_3\text{C}_6\text{H}_5\text{O}_7$  will be produced?



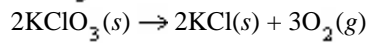
8. If 8.00 mol of  $\text{NH}_3$  reacted with 14.0 mol of  $\text{O}_2$ , how many moles of  $\text{H}_2\text{O}$  will be produced?



9. If 8.6 L of  $\text{H}_2$  reacted with 4.3 L of  $\text{O}_2$  at STP, what is the volume of the gaseous water collected (assuming that none of it condenses)?



10. The decomposition of potassium chlorate yields oxygen gas. If the yield is 95%, how many grams of  $\text{KClO}_3$  are needed to produce 10.0 L of  $\text{O}_2$ ?



## Appendix B. Student Prompts.

Name \_\_\_\_\_ Age \_\_\_\_\_  
Gender \_\_\_\_\_ Race \_\_\_\_\_  
Year in School \_\_\_\_\_

Do you have a computer at home?

If yes, does it have Internet access?

Have you ever taken an online class?

How often you use the Internet?

How comfortable are you with a computer?

Is this your first chemistry class?

Did you take physical Science?

Are you currently enrolled in a math class?

If yes, what math class are you currently in?

What math class do you complete last year?

Do you think that you learned a lot of chemistry from this unit?

What part did you learn the most from?

Did you enjoy this unit?

What was your favorite part?

Did you like using the computer for the activities?

What was the best part of using the computer?

Did you have computer problems?

If yes, what problems did you have?

Was this unit different from what you have done in your science classes before?

How was it different?

How would you rate the web site "Curriculum Pathways" based on the ease of use?

How would you rate the content of the web site "Curriculum Pathways"?

What was the most helpful part of the web site "Curriculum Pathways"?

What was the most difficult part of the web site “Curriculum Pathways”?

On a scale of 1-10, with 1 being low and 10 being high, what overall rating would you give the web site “Curriculum Pathways” and why?