

**Development and Evaluation of a Standards-Based Approach to Instruction
in General Chemistry**

by

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Abstract

Operation CHEM1251 is an on-going project designed to implement a Standards-based approach to instruction in the general chemistry curriculum at the University of North Carolina at Charlotte. The project is a collaborative effort between the Department of Chemistry and the Department of Middle, Secondary, and K-12 Education. Implementation of such an approach has shown an increase in both student performance and attitude toward chemistry. A Standards-based approach to instruction includes, but is not limited to, block scheduling the entire enrollment of one lecture class into the same laboratory sections and learning experiences structured in a learning cycle format. Analysis of the data gathered during this project indicates that this is the first time in five years that any day-time first semester general chemistry course section scored significantly higher than other concurrent sections on both departmental exams and the American Chemical Society's Nationally Standardized End of Semester Exam.

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Introduction

Over the past decade, various commissions and government panels have reported a lack of science literacy among young people, accompanied by negative attitudes toward science (Carnegie Forum on Education and the Economy, 1986; Commission on the Skills of the American Workforce, 1990; National Commission on Excellence in Education, 1983; National Governor's Association, 1991). To them, science is perceived as boring, irrelevant, and difficult to learn. University level general chemistry courses are not immune to this national problem, and both low student performance and interest have been observed and documented in these introductory courses (Barrow, 1994; National Science Foundation, 1987). Not surprisingly, groups concerned about the important role that science and technology play in society have issued a clarion call for science education reform (American Association for the Advancement of Science, 1993, 1989; National Research Council, 1996; National Science Foundation, 1996; National Science Teachers Association, 1992).

One way for institutions of higher education to assist in the reform effort is to offer science courses that use the *National Science Education Standards* approach to instruction (National Research Council, 1997, 1996). Traditional chemistry teaching in high enrollment courses relies heavily on lecture in which the presentation of chemical concepts and equations are to be scribed, memorized, and reproduced by students (Zoller, 1999). By comparison, a

Standards-based approach to instruction includes, but is not limited to, the incorporation of inquiry, reflection, critical discourse, and collaborative learning experiences. For example, a Standards-based approach in a large lecture hall would first discuss the very basics of a subject area, observe a demonstration of a chemical event, and then discuss and explain the event in terms of the specific subject with the ultimate goal of facilitating the students to decipher the phenomena and fully develop the concepts involved in a manner that they understand and can communicate to others. In contrast, a traditional lecture may show the demonstration of the specific chemical phenomenon after the instructor has explained all the chemical concepts to the students with little, if any, discussion. In a Standards-based environment, chemistry instructors become facilitators helping students in the construction of their knowledge instead of dispensers of facts and concepts. In addition, the Standards-based curriculum allows for a student-centered environment, rather than one where the instructor is the sole source of information and knowledge.

The general chemistry program at The University of North Carolina at Charlotte has experienced both low student interest and performance in the introductory chemistry course (CHEM1251) course. CHEM1251 is the first semester general chemistry course for science, secondary science education, and engineering majors. The university is a comprehensive four-year institution with a student population of approximately 17,000 and is increasing at a rate of 3-4 % annually. The ethnicity of students in this course is similar to that represented in the university, and the breakdown of full-time students during the period of this research is as follows: 16.92 % African-American, 0.43% American Indian/Alaskan native, 4.36% Asian/Pacific Islander, 1.67% Hispanic, 3.14 % non-resident alien, and 73.40% Caucasian. Approximately 800 students enroll in CHEM1251 each year, and the average class size for

daytime sections is 84 with a range of 32-132 from fall 1993 to the spring 1999 semester.

Students often begin the course knowing that the proportion of “D” and “F” grades assigned at the end of the semester is alarmingly high. In addition, students often believe that chemistry is the “weedout” course for science majors. As a result, the vast majority of the students carry preconceptions that the course is very difficult and that they will not do well.

In years prior to the initiation of the project described in this paper, the chemistry department has attempted to increase student performance in CHEM1251 by tracking students into different sections based on their ability, by implementing various instructional strategies, such as in-class work sheets, and by incorporating additional resources into the curriculum such as supplemental instruction. In addition, a number of interactive learning experiences, such as demonstrations, were incorporated into the lecture session. All of these changes were made with the hope of increasing student interest, involvement, and achievement. While a great amount of effort had been placed on improving the presentation of material, the primary method of instruction remained passive didactic lecture. In addition, lecture and laboratory were disjointed with respect to the logistical presentation of chemical content and concepts, a common occurrence at many universities and colleges. As such, the above changes resulted in no improvement in student performance. However, course and instructor evaluations showed an improvement in student attitude toward chemistry when interactive learning experiences were incorporated into the lecture. This lead us to the hypothesis that student interest, motivation, and performance would all increase if both the curriculum and instructional strategy were redesigned and grounded in the tenets of the *National Science Education Standards (NSES)*. Our effort to implement a Standards-based approach into CHEM1251 has been termed Operation CHEM1251.

Project Description

Goals and Objectives

It has been well documented that lecture presentations are a passive style of learning and offer little to involve students in the learning process (Ausubel, 1963; National Science Foundation, 1989; von Glasersfeld, 1995). The NSES call for the use of open-ended inquiry in science instruction. Unlike lecture presentations, inquiry actively involves students in the learning process. As such, it is hypothesized that both student performance and affect will increase if the curriculum were aligned with the tenets of the NSES. The major goal of Operation CHEM1251 was to develop and implement a curriculum and an approach to teaching chemistry that was aligned with the *National Science Education Standards*. For the purposes of this project, a standards-based approach to instruction includes the use of: 1) open-ended inquiry, 2) collaborative learning, 3) active participation during lecture sessions, 4) incorporation of relevant material, and 5) integration of the laboratory experiences with the lecture material. Each of these individual elements have been shown to promote student understanding (Bunce, Gabel, Herron, & Jones, 1997; Staver, 1998). The focus of this project was to collect baseline data in a traditional lecture hall classroom, incrementally introduce aspects of the standards-based curriculum over a four semester period into one course section using the other concurrent CHEM1251 course sections as the control group, and assess the effect of incorporating the new teaching and learning strategies. The integration of these teaching techniques into CHEM1251 occurred over the four semester period from the fall of 1997 to the spring of 1999.

Course Development

Four to eight sections of CHEM1251 were offered each semester for the past two years (fall 1997 – spring 1999). One section each semester, taught by one of the authors, was the experimental section. The author who taught the class obtained a doctorate degree in chemistry.

Other course sections comprised the control group and were taught by other chemistry department faculty.

In the fall 1997 semester, the first semester of Operation CHEM1251, the experimental section was taught in a traditional lecture format similar to the seven other concurrent course sections. Questions posed to the students were usually in a rhetorical manner, although questions asked by the students were occasionally addressed during the lecture. The lectures did not allow time for students to formally interact with each other. The laboratory portion of the curriculum was offered as a separate one credit hour course that met once per week for 3 hours. Approximately 80% of the students were concurrently enrolled in both the lecture and lab courses, although the enrollment into the 18 laboratory sections was completely random. Essentially, the composition in any one laboratory section consisted of students from any and potentially all of the 8 lecture sections offered. The laboratory format included having students conduct an experiment and write an open-ended lab report on their findings. The laboratory curriculum did not completely follow the order of topics introduced in the lecture. The course format and curriculum were the same for all CHEM1251 course sections, and the four mid-term exams and the final exam were the same for every lecture section. The mid-term exams consisted of 25-32 multiple-choice questions created through a collaborative effort by all CHEM1251 instructors teaching during the semester. The final exam was the American Chemical Society (ACS) Standardized Exam (1997 version) for First Semester General Chemistry.

In the spring 1998 and fall 1998 semesters, the control sections continued in the same format as described for the fall 1997 semester while changes in the experimental section were initiated to systematically incorporate a standards-based curriculum. Simple collaborative

learning exercises were introduced into the experimental section for the sole purpose of actively engaging students in class. For example, instead of using rhetorical questions during the lecture, students formed groups and worked collaboratively on problems. While students worked to solve specific problems presented, the instructor circled the room monitoring progress, asking questions, and addressing specific questions posed by students. Afterwards, the instructor worked through the solution using student input to solve the problem. The collaborative problem solving exercises were typically incorporated after the topic was formally introduced, which is not consistent with the tenets of constructivist learning (Staver, 1998; von Glasersfeld, 1995) and the learning cycle approach (Renner & Marek, 1988). The constructivist philosophy and the learning cycle instructional strategy are the foundation for standards-based instruction.

Nonetheless, the interactive portion of the lecture allowed students to work with each other and solve problems with the instructor in the role as a guide. This instructional strategy was incorporated to a greater extent in the fall 1998 semester than in the previous spring semester.

The spring 1998 semester also marked the beginning of interactive lecture notes. These notes, created by the authors, were made available to the students at the beginning of the semester through the campus bookstore. The purpose for providing the “Interactive Lecture Notes and

students would normally use to copy problems and notes from the board and increase the amount of time spent on task discussing concepts, solving problems, and interacting with each other and the instructor. The notes were incomplete and required the students to follow along during class. Many of the interactive exercises used in the class were included in the notes, but other examples and concepts not specifically covered in the notes were incorporated into the curriculum. The interactive lecture notes and the collaborative exercises were the only two significant changes made to the experimental course during the spring 1998

and fall 1998 semesters. The four mid-term exams and the ACS final exam were common for all concurrent sections during these semesters.

In the spring 1999 semester, the control group continued as before in previous semesters while the experimental section continued its development into a standards-based curriculum. The sequence of introducing concepts that more closely approximated a constructivist and learning cycle approach to teaching and learning was incorporated in the experimental section. During this semester, chemical concepts and relationships were only presented in class to the point at which students would have the prerequisite background needed to start working collaboratively on a problem. In this way, students used prior knowledge and dialogued possible ways to complete and solve the problem to the best of their ability. In addition, students were often asked to discuss problems and share their understanding of chemical concepts and principles prior to any formal presentation in class. This was a significantly different approach from the previous semesters when collaborative exercises were conducted only after formal presentation of the topic. The spring 1999 semester also differed in the use of demonstrations. Demonstrations have always been a part of the CHEM1251 curriculum, but the demonstrations in the spring 1999 experimental section were used as exploration into a topic. For example, one demonstration, used to exemplify the density of gases, was the creation of soap bubbles from carbon dioxide by exhaling into a tube connected to the bubble wand, or from pure argon from a gas cylinder, or from methane gas from a valve in the classroom. No information was given before the demonstration other than to simply observe and explain what occurred. As the students developed their explanation of the observed event, the instructor would guide the discussion toward the concepts of gas densities, gaseous diffusion, and how the ideal gas law can

be used to explain and measure these properties. In previous semesters, the demonstration followed the formal presentation of gas densities.

Registration for the experimental lecture section in the spring 1999 semester was restricted in a manner that required students to also register for the one corresponding experimental CHEM1251 laboratory section, which was also taught by the investigator. Block scheduling, in which the same group of students are enrolled in the same lecture course section and set of corresponding lab sections, was instituted to increase interaction among the group of students in the experimental section during both lab and lecture, and to allow discussion of lecture concepts in the laboratory. The topics investigated in the laboratory were also discussed periodically in the lecture. Although the laboratory curriculum did not completely follow the lecture curriculum, whenever possible, results and conclusions recorded by the students were used to more fully develop concepts in the lecture and to show the connection between the laboratory and lecture. Due to logistical and laboratory facility constraints, enrollment of the experimental section was restricted to 32 students. An enrollment of 32 students falls at the lower end of the range for CHEM1251 class size. The three other concurrent sections had enrollments of 48, 87, and 104. Historically, CHEM1251 class sizes have ranged from 27 to 132 with an average of 78 students. The correlation of class size with performance in CHEM1251 was investigated over the previous five years, and the findings as they relate to the evaluation of the Operation CHEM1251 project are presented later in this article.

Methods of Analysis

Several instruments were utilized to measure the effect of the standards-based curriculum on performance and attitude. Background academic performance comparison between the experimental and control groups was investigated through the use of SAT scores and a student

pre-semester assessment (SPSA). The SPSA is a multiple-choice exam consisting of 10 math questions and 10 chemistry questions administered during the first week of the semester. The math questions focused mainly on algebra and conversion between units. The chemistry questions were designed in a manner so that even if students had no formal chemistry experience, they should still be able to analyze the information in the question to determine the correct answer. The purpose of the SPSA was to compare students between the experimental and control groups on prerequisite math ability and prior chemistry knowledge (Wagner & DiBiase, 2000). Although CHEM1251 does not require any previous formal chemistry course work, approximately 90 percent of the students enrolled in CHEM1251 have had at least one semester of chemistry, typically from high school. The 20-question SPSA is shown in Appendix 1. A demographic and preconceptions of chemistry survey was also administered at the beginning of the semester to compare relative differences in background and attitude toward chemistry between the control and experimental groups. The seven categorical questions investigated on the demographic survey are shown in Appendix 2, and the 11 Likert scale questions on the preconceptions of chemistry survey is shown in Appendix 3.

In addition, a two-part survey was administered approximately halfway through the semester. The first section consisted of six questions used to identify the reasons students enrolled in their respective CHEM1251 course sections (Appendix 4). The purpose for including this survey was to confirm that course selection was not due to students' knowledge that the experimental section was unique or giving special attention through a revised curriculum. The second part of the mid-semester survey compared the intrinsic and extrinsic motivation of students in both the experimental and control groups (Appendix 4). These questions were based on an instrument developed at the University of Michigan (Pintrich, Smith, Garcia, &

McKeachie, 1991). The four intrinsic and four extrinsic motivation questions were not specific to the course, but rather, questioned students on motivation inherent to their personalities. All questions on the mid-semester survey were Likert scaled questions ranging from one to five. Although the motivation questions and reasons for enrolling in a specific course section could have been administered at any time during the semester, these surveys were postponed until later in the semester in an effort in to limit the number of surveys administered at the beginning of the semester. End-of-semester course evaluations were used to investigate students' satisfaction with the course, including the teaching methods employed in both the experimental and control groups. This 18 question Likert scale survey was administered within the last two weeks of the course (Appendix 5). Academic performance in the CHEM1251 course was monitored through four common exams and the ACS end of semester exam.

Statistical tests for significance difference between the experimental and control groups for Likert scaled and continuous data were analyzed through student t-tests. This included data collected from the preconceptions of chemistry survey, SPSA, SAT, reasons for enrolling in a specific course section, intrinsic and extrinsic motivation, and course exam averages. Chi-squared analyses were used to identify possible significant differences in the categorical demographic data. The scores recorded for the experimental group's end-of-course evaluation were compared to the average and standard deviation of the control group for all 18 questions on the evaluation instrument.

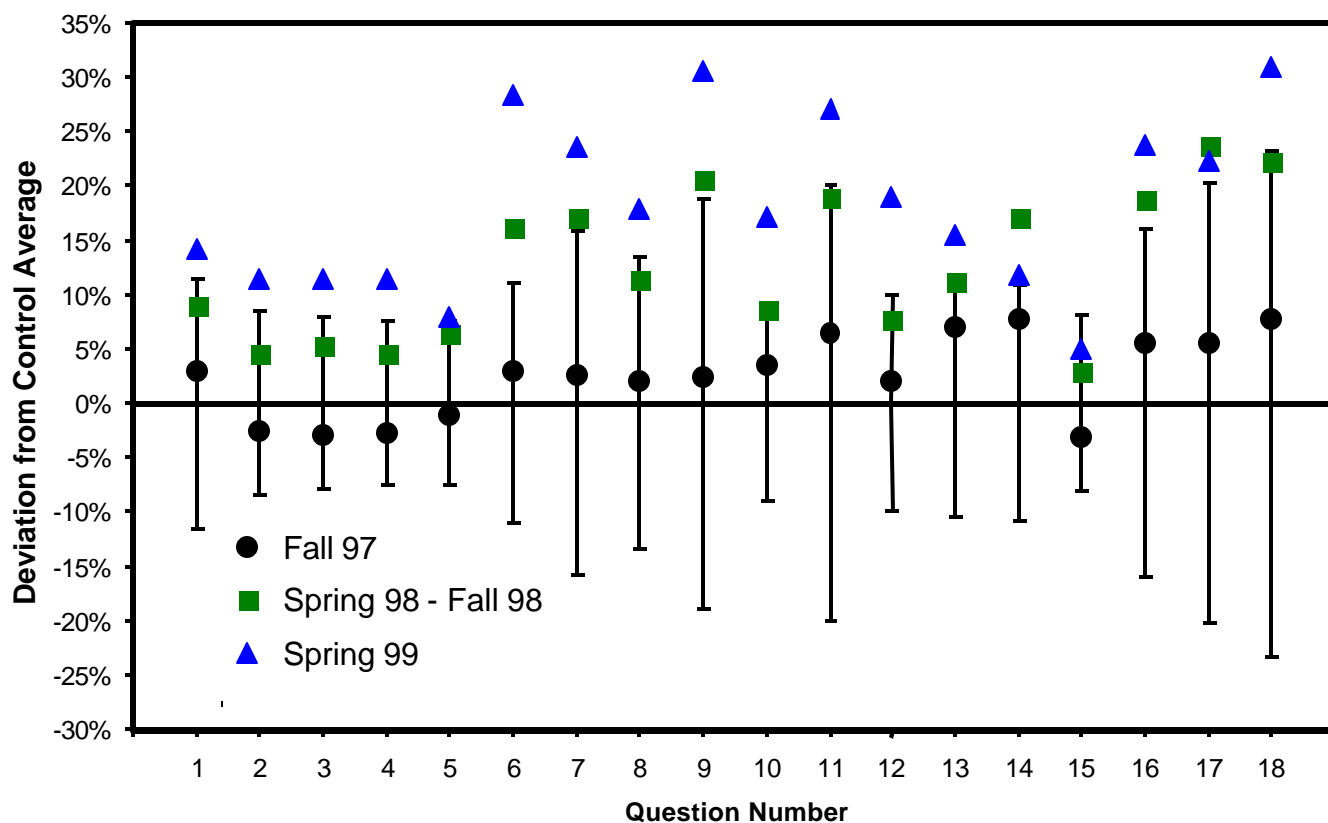
Results and Discussion

Analysis of data from the fall 1997 semester showed no significant difference in the SAT, SPSA, PGI, and previous number of chemistry courses taken between the experimental section and control sections. End-of-course evaluations by the students also showed no significant

difference between the experimental and the control sections in their opinions on the quality of the course in the fall 1997 semester (Figure 1).

Figure 1

End of Semester Course Evaluations for CHEM1251. The control group average for each question is set at zero and the error bars represent the standard deviation on the average of each question for all control group CHEM1251 courses over the two-year research period. The symbols on the graph represent the experimental section scores. The specific questions on the evaluation are shown in Appendix 5.



Exam performance in the experimental group during this initial semester showed no statistically significant difference for the exam averages (Table 1).

Table 1

CHEM1251 Exam Averages. Student *t*-tests were used to compare the experimental group to the control group. The alpha (***a***) value was set at 0.05, and the variable *n* represents the number of class sections in each group. In the spring of 1999, there was a significant increase in the experiment group's performance on both the mid-term exams and the ACS Nationally Standardized Exam.

Variable	Experimental	Control	% difference	<i>P</i> Value
Fall 1997 Exam Average	59.8 (<i>n</i> =1)	62.0 (<i>n</i> =4)	-3.50	0.123
Spring 1998 Exam Average	59.9 (<i>n</i> =1)	58.0 (<i>n</i> =2)	3.41	0.232
Fall 1998 Exam Average	62.8 (<i>n</i> =1)	61.6 (<i>n</i> =5)	2.03	0.317
Spring 1999: Average for the four mid-term exams	68.4 (<i>n</i> =1)	61.8 (<i>n</i> =3)	10.6	0.0233
Spring 1999: ACS Final Exam Average (number correct out of 70 questions)	45.0 (<i>n</i> =1) 68 th national percentile	37.4 (<i>n</i> =3) 42 nd national percentile	16.9	0.0218

Analysis of data from the spring 1998 and fall 1998 semesters once again showed no statistically significant difference between the experimental and control sections with respect to student's demographic data, perceptions of chemistry, academic backgrounds, or academic performance. Improvement in end-of-course evaluation for the experimental section in the spring 1998 and fall 1998 semesters over the fall 1997 semester were recorded for all 18-opinion questions on the evaluation form. Furthermore, significant improvement over the control group in seven of the eighteen questions was observed (Figure 1). It is very reasonable to conclude that the collaborative learning style that was implemented during these semesters, and the incorporation of the lecture notes were a major factor for this increase in student satisfaction of the course. The exam averages for the experimental group improved during these two semesters, but were not statistically different from the control group (Table 1).

Analysis of the data collected in the spring 1999 semester for all background variables (SAT, SPSA, demographic questions, reason for enrolling in specific course section, preconceptions of chemistry, and motivation inherent to personality) indicate that there was a homogeneous population between the experimental section and the three other control sections (Table 2). Analysis of data from the experimental group showed a significant increase in both student performance and course satisfaction. The experimental group scored a significant 10.7 percent higher on the four common exams and 16.9 percent higher on the ACS End-of-Semester Final Exam (Table 2). The averages for the ACS exam placed the experimental section in the 68th percentile of the nation and the control group in the 42nd percentile of the nation. This is the first time since data collection on exam averages began over five years ago that any daytime CHEM1251 course section scored significantly higher than other concurrent sections.

Table 2

Comparison of Background Variables Between the Experimental and Control Groups for the Spring 1999 Semester. The fourth column shows the *p* value obtained through the statistical methods outlined in the article. In all cases, the alpha (α) value was set at 0.05. The variable *n* represents the number of course sections in each group. In all cases, the null hypothesis was supported indicating no significant difference between the experimental and control groups on the background variable.

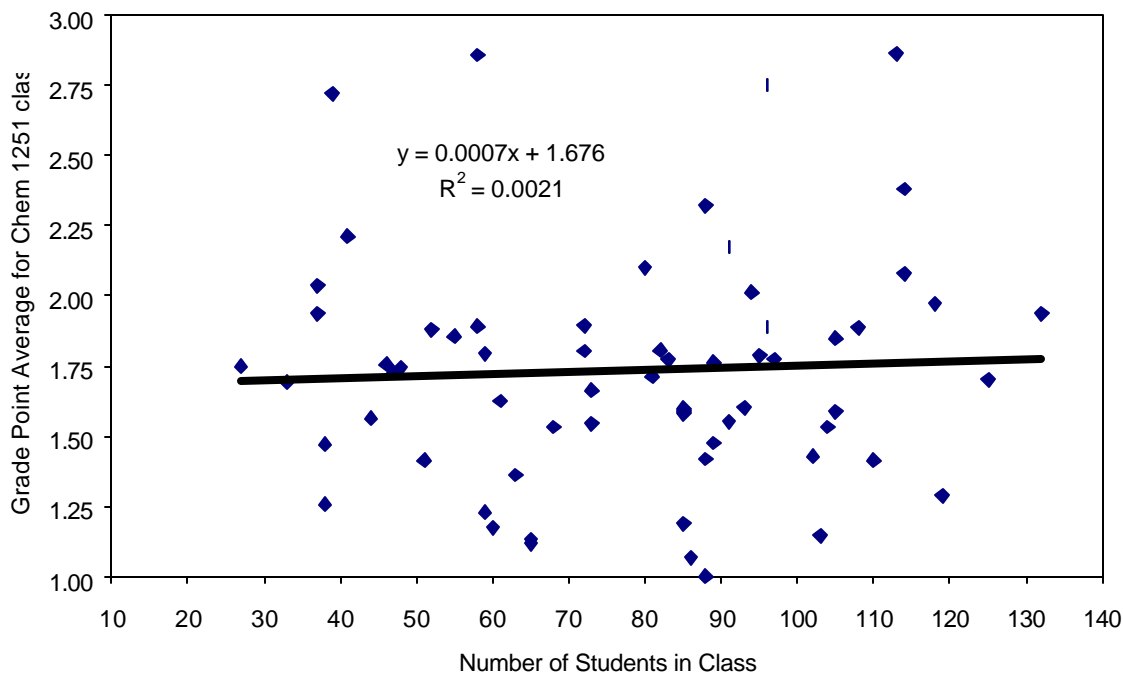
Variable	Experimental Average (<i>n</i> = 1)	Control Average (<i>n</i> = 3)	<i>P</i> Value
<u>ACADEMIC PERFORMANCE</u>			
SAT Total	990	1017	0.21
SAT Math	513	522	0.31
SAT Verbal	487	494	0.22
SPSA	65.1	63.9	0.35
<u>DEMOGRAPHICS</u>			
Previous number of semesters of chemistry			0.41
Age			0.11
Involvement in University activity			0.26
Hours of work at job per week			0.95
Highest level of math			0.35
High school town size			0.20
Year in college			0.69
<u>COURSE SECTION SELECTION</u>			
Reasons for enrolling in specific course section (scale 1-5)	1.43	1.27	0.17
<u>PRE-CONCEPTIONS OF CHEMISTRY AND COURSE</u>			
Preconceptions of chemistry (scale 1-5)	1.62	1.34	0.12
<u>MOTIVATION</u>			
Intrinsic motivation (scale 1-5)	2.57	2.42	0.12
Extrinsic motivation (scale 1-5)	3.28	3.07	0.24

Student retention in the experimental section was also greater. The total number of withdrawals from CHEM1251 for the spring 1999 semester was 34, and all of them came from the control group. Eighty one percent of the students in the experimental section completed all four common exams and the final exam while 73 percent of the students in the other three course sections completed all exams. This is an indicator of the number of students that did not withdraw, but stopped coming to class. The D/F ratio in the experimental section was 25.8 percent compared to 44.5 percent in the control group. The end-of-semester course evaluations were statistically higher than the control group in 17 of the 18 opinion questions (Figure 1). Question number 15 was the only question that was not statistically higher and asked students for their opinion on the textbook, which is the same for all CHEM1251 sections.

The class size for the experimental group for the spring 1999 semester was 31. Compared to the three control sections with populations of 48, 87, and 104, the experimental section appeared to have a distinct advantage. To address this issue, a retrospective study was conducted to determine the correlation between CHEM1251 course performance and class size for the past five years. A total of 65 CHEM1251 course sections were offered over the period from the fall 1993 semester through the summer 1998 semester. Class populations ranged from 27 to 132 with an average of 78 students. Data analysis indicated only a 0.046 correlation between class size and class performance. The skewness of this distribution was 0.077, indicating that the range in class sizes was normally distributed about the mean for this sample population (Figure 2). This data suggests that there was very little correlation between these two variables over this five-year period. There is also evidence in the literature suggesting that class size has little effect on performance once the number of students exceeds seventeen (Gilbert, 1995; Williams, Cook, Quinn, & Jensen, 1985; Ziegler, 1997). The results from this

Figure 2

The Effect of Class Size on Class Performance. This data was compiled from CHEM1251 courses offered over the period from the fall 1993 through the summer 1998 semesters.



retrospective study of class size in CHEM1251 together with support of the literature demonstrate that the difference in class sizes between the experimental and control groups was unlikely to be a significant contributor to any differences noted in academic performance between these two groups. To substantiate the conclusions drawn from these analyses, the experimental class size will be increased in future research efforts.

Conclusion and Future Considerations

The results from the first phase of Operation CHEM1251 show that there was little difference in background, attitude, and ability among students in different course sections at the beginning of each semester from the fall 1999 to the spring 1999 semesters. When the

experimental course section was taught in a similar lecture style to those in the control group, the class performed at the same level as the control group. As incremental changes were made starting in the spring of 1998, an increase in performance and attitude was recorded. Significant increase in performance and class satisfaction was recorded in the spring 1999 semester when the complete incorporation of the constructivist philosophy and learning cycle approach to learning was realized. There are several potential factors that may have caused the increase in performance and attitude. These factors include the following; students in the experimental section having both laboratory and lecture together, relatively smaller class size, motivational factors not measured, and possibly the random event that many “good” students enrolled in the same section. However, other subtle changes occurred in the curriculum without any conscious effort on the part of the instructor. For example, a better relationship developed among the students and the instructor as a result of having the same instructor for both laboratory and lecture. A more congenial and open relationship also evolved among the students and between the instructor and the students as a result of the incorporation of interactive collaborative exercises during lecture. This in turn decreased the anxiety of the students, which normally runs at a high level in this course. The affect of social interaction on academic performance can be an elusive topic, but it certainly appeared to have an overall positive effect on the experimental section. Other research has demonstrated the importance of socialization on academic performance and attitude toward learning (Aronson, 1987; Gleason, 1986; Lockie & Van Lanen, 1994). A very natural crossover of topics in laboratory and lecture occurred when the two curricula were synchronized, and the relationship continued to grow in both pre-laboratory lectures and classroom lectures as the semester progressed. While there may still be other small factors contributing to increased performance, there does not appear to be any one overwhelming

baseline factor affecting this difference in performance. There is a very good indication that the Operation CHEM1251 curriculum and teaching method did significantly increase both student performance and affect.

In phase two of this project, the enrollment for the experimental section will be increased to 96, and teaching assistants will be used as the instructors for the three corresponding laboratories. This size enrollment is near the average enrollment of CHEM1251 and accommodates three lab sections that will be scheduled to meet at the same time each week. Qualitative interviews will be conducted on a sampling of the experimental and control groups to investigate their views on the relationship of the laboratory experiments to the lecture material. The laboratories will be split into two 90 minute meeting, rather than one three-hour meeting, to implement the learning cycle approach more appropriately. Lecture will meet twice a week followed immediately by the 90-minute laboratory that will put into practice the concepts discussed in lecture as well as explore concepts that will be discussed in the following lecture. The investigators will act in a supervisory role during the laboratories sessions and aid in showing both the teaching assistants and the students the content connection between laboratory and lecture. The lecture will be further developed and refined in the tenets of the standards-based approach to learning. New laboratory experiments will also be developed to more closely follow the material covered in lecture. It is anticipated that a class enrollment typical of CHEM1251 sections along with complete correlation of the laboratory and lecture curricula and the full implementation of the developed teaching strategy will provide further evidence on the positive impact of the Operation CHEM1251 curriculum. In fact, preliminary data analysis from successive semesters indicate a continuation of higher performance by students in the

experimental section compared to the control sections, and the authors plan to publish these results in the near future.

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Appendix 1*Student Pre-Semester Assessment (SPSA).*

- 1) Complete the following calculation: $(3.0 \times 10^{-12}) \times (4.0 \times 10^6) = ?$
- 12×10^{-72}
 - $12 \times 10^{-1/2}$
 - 1.2×10^{-5}
 - 7.0×10^{-6}
 - 1.2×10^{-6}
- 2) Using the equation provided, calculate the number of moles in 80.0 g of CH_4 . The molecular mass of $\text{CH}_4 = 16 \text{ g/mole}$.

$$\left(\frac{\text{grams}}{\text{molecular mass}} \right) = \text{moles}$$

- 16 moles
 - 1280 moles
 - 5.0 moles
 - 80 moles
 - 0.20 moles
- 3) The density of copper is 10.0 g/mL. What is the volume in mL of a 2000 g ingot of copper?
- 200 mL
 - 5.00×10^{-4} mL
 - 2.00×10^4 mL
 - 20.0 mL
 - 100 mL
- 4) Matter can undergo physical and chemical property changes. Which of the following is an example of a physical property change?
- Sulfuric acid corrodes metals.
 - Gunpowder explodes when ignited.
 - Gasoline burns.
 - Solid lead becomes liquid above 600 °C.
 - Milk turns sour.
- 5) What is the expected formula of a neutral compound formed by combining the ions sodium (Na) with a +1 charge and sulfur (S) with a -2 charge?
- Na_2S
 - NaS
 - Na_2S_2
 - NaS_2
 - Na_2S_3

- 6) Which one of the following should be most similar in chemical properties to germanium, ${}_{33}^{73}\text{Ge}$?
- ${}_{74}^{184}\text{W}$
 - ${}_{50}^{118}\text{Sn}$
 - ${}_{31}^{70}\text{Ga}$
 - ${}_{33}^{75}\text{As}$
 - ${}_{16}^{32}\text{S}$
- 7) Which of the following classifications of electromagnetic radiation has the greatest amount of energy associated with it?
- ultraviolet radiation , the wavelength is approximately 2×10^{-9} meters
 - microwaves, the wavelength is approximately 1×10^{-3} meters
 - radio waves, the wavelength is approximately 10 meters
 - infrared radiation, the wavelength is approximately 10×10^{-6} meters
 - x-rays, the wavelength is approximately 1×10^{-10} meters

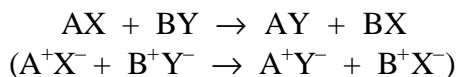
- 8) Use the equation provided to calculate the energy associated with electromagnetic radiation possessing a frequency of 4.0×10^{14} Hz? The units for each parameter are in parentheses.

$$\begin{aligned} \text{Energy} &= 6.6 \times 10^{-34} \quad \times \text{ Frequency} \\ \text{(joules)} &= \text{(joules x seconds)} \times \quad \text{(Hz)} \end{aligned}$$

- 10.6×10^{-20} Joules
 - 6.1×10^{47} Joules
 - 1.6×10^{-48} Joules
 - 2.6×10^{-19} Joules
 - 2.6×10^{-476} Joules
- 9) The frequency of light (ν) is inversely proportional to its wavelength (λ) through the speed of light constant (c). What is the formula of the equation described by this statement?
- $n = \frac{l}{c}$
 - $n = cl$
 - $n = \frac{c}{l}$
 - $nc = l$
 - $\frac{n}{l} = c$

- 10) Ions are atoms with an associated electrostatic charge, and atoms are made up of protons (+1 charge), neutrons (0 charge), and electrons (-1 charge). Which of the following statements is **not correct**?
- a) Ions are formed by adding electrons to a neutral atom.
 - b) Ions are formed by changing the number of neutrons in an atom's nucleus.
 - c) Ions are formed by removing electrons from a neutral atom.
 - d) An ion has a positive or negative charge.
 - e) Metals tend to form positive ions.
- 11) Solve the following equation for Z. $15 = \frac{5Z}{2 - (3 \times 4)}$
- a) -5
 - b) 0.033
 - c) 30
 - d) -30
 - e) 12
- 12) The more molecules and atoms move around, the greater their energy. In which state, solid, liquid, or gas, do the molecules of water have the highest average kinetic energy?
- a) gas
 - b) liquid
 - c) solid
 - d) all states are the same
- 13) How many oxygen atoms are represented in the formula $\text{Al}_2(\text{SO}_4)_3$?
- a) 3
 - b) 4
 - c) 7
 - d) 12
 - e) 2
- 14) Physical properties can be either intensive (independent on the size of the sample) or extensive (dependent on the size of the sample). Which one of the following is an extensive property?
- a) density
 - b) mass
 - c) boiling point
 - d) freezing point
 - e) temperature

- 15) According to the ideal gas law $PV = nRT$
 (Pressure x Volume = Number of moles x Constant x Temperature)
 if the volume and number of moles of a gas sample are held constant, as the temperature increases the pressure will _____.
- increase
 - decrease
 - remain the same
- 16) According to the equation $2 \text{Fe}(\text{OH})_3 + 3 \text{H}_2\text{SO}_4 \rightarrow 6 \text{H}_2\text{O} + \text{Fe}_2(\text{SO}_4)_3$, it takes 2 moles of $\text{Fe}(\text{OH})_3$, and 3 moles of H_2SO_4 to make 6 moles of water (H_2O). How many moles of $\text{Fe}(\text{OH})_3$ and H_2SO_4 are necessary to make 18 moles of water?
- 18 moles of $\text{Fe}(\text{OH})_3$ and 18 moles of H_2SO_4
 - 6 moles of $\text{Fe}(\text{OH})_3$ and 9 moles of H_2SO_4
 - 2 moles of $\text{Fe}(\text{OH})_3$ and 3 moles of H_2SO_4
 - 4 moles of $\text{Fe}(\text{OH})_3$ and 6 moles of H_2SO_4
 - 9 moles of $\text{Fe}(\text{OH})_3$ and 6 moles of H_2SO_4
- 17) An empirical formula of a compound is much like the lowest whole number ratio. Which one of the following molecular formulas is also an empirical formula?
- $\text{C}_6\text{H}_6\text{O}_2$
 - $\text{C}_2\text{H}_6\text{SO}$
 - H_2O_2
 - $\text{H}_2\text{P}_4\text{O}_6$
 - $\text{C}_6\text{H}_{12}\text{O}_6$
- 18) In a metathesis reaction, positive ions and negative ions exchange “partners” and conform the following general equation:



All products created as well as the reactants are neutral in their overall charge. What products are formed in the metathesis reaction when HCl (the charges on the atoms are H^{+1} and Cl^{-1}) reacts with NaOH (the charges on the atoms are Na^{+1} and OH^{-1}) ?



- $\text{NaOH}_2^+ + \text{Cl}$
- $\text{NaCl} + \text{H}_2\text{O}$
- $\text{NaH} + \text{ClOH}$
- $\text{H}_2 + \text{NaCl} + \text{O}^{-2}$
- $\text{NaCl} + \text{HO}$

19) Ionic compounds are created by joining a metal and nonmetal together. Which of the following is most likely to be an ionic compound?

- a) NF_3
- b) NaCl
- c) CO_2
- d) CN
- e) CH_4

20) How many milliliters are in 2 gallons of water?

1 gallon = 3.8 liters

1 liter = 1000 milliliters

- a) 3800
- b) 3.8
- c) 7600
- d) 526
- e) 2000

Appendix 2

Demographic Survey. These questions were administered at the beginning of the semester.

- 1) How many semesters of general chemistry have you had? Include all high school and college courses regardless of the grade received.
 - (a) 0
 - (b) 1
 - (c) 2
 - (d) 3
 - (e) 4 or more

- 2) What is your age?
 - (a) 15-18
 - (b) 19-21
 - (c) 22-24
 - (d) 25-28
 - (e) older than 28

- 3) Are you involved with any official University extra-curricular activity (e.g. sports teams, music, speech team, etc.)?
 - (a) Yes
 - (b) No

- 4) Do your plans include employment during this semester ?
 - (a) I do not plan to work.
 - (b) I plan on working less than 10 hours per week.
 - (c) I plan on working 10-20 hours per week.
 - (d) I plan on working 21-40 hours per week.
 - (e) I plan on working greater than 40 hours per week.

- 5) What is the highest level math course that you have taken or are currently enrolled in this semester? Include any high school or college courses.
 - (a) I have not taken any math courses as advanced as Algebra.
 - (b) Algebra, and/or Trigonometry
 - (c) Precalculus
 - (d) Calculus I
 - (e) Calculus II or higher

- 6) Which describes the area in which you lived during high school?
 - (a) Rural area
 - (b) Small town (20,000 or less)
 - (c) Moderate size city (20,001 – 60,000)
 - (d) Large city (60,001 – 100,000)
 - (e) Urban area (more than 100,000)

- 7) What class are you in?
 - (a) Freshman
 - (b) Sophomore
 - (c) Junior
 - (d) Senior
 - (e) Post-baccalaureate or non-traditional student returning back to school.

Appendix 3

Preconceptions of Chemistry Survey. All questions were Likert scaled from 1 (strongly agree) to 5 (strongly disagree). This survey was administered at the beginning of the semester with the SPSA.

- 1) I will not do very well in chemistry class.
- 2) Chemistry classes are boring.
- 3) Chemistry has no practical application.
- 4) Chemists are stereotypical "nerds" or "geeks".
- 5) Chemistry instructors are intimidating.
- 6) Chemistry is a very difficult subject to understand.
- 7) I plan on learning only enough material in this class to get me the grade that I need.
- 8) I do not plan on taking any more chemistry classes.
- 9) I would never consider taking a chemistry class as an elective.
- 10) Chemistry laboratory classes are intimidating.
- 11) I will not learn anything useful in a chemistry laboratory class.

Appendix 4

Inherent Motivation and Course Selection Survey. All questions were Likert scaled from 1 (not true for me) to 5 (very true for me). These questions appeared in a random order on the survey but are shown here in their groupings. This survey was administered at the mid-point of the semester.

Reasons for selecting course section

- 1) I chose this class section because of the instructor.
- 2) I chose this class section because it fit my schedule.
- 3) I chose this class section because it was the only section that was still open for registration.
- 4) I chose this class section because I knew it would be taught in a style in which I would be able to learn.
- 5) I chose this class because I knew the class size would be small.
- 6) I chose this class because I knew it was a special experimental course section.

Intrinsic motivation

- 1) In a class like this, I prefer course material that really challenges me so I can learn new things.
- 2) In a class like this, I prefer course material that arouses my curiosity, even if it is difficult to learn.
- 3) The most satisfying thing for me in this course is trying to understand the content as thoroughly as possible.
- 4) When I have the opportunity in this class, I choose course assignments that I can learn from even if they don't guarantee a good grade.

Extrinsic motivation

- 1) Getting a good grade in this class is the most satisfying thing for me right now.
- 2) If I can, I want to get better grades in this class than most of the other students.
- 3) The most important thing for me right now is improving my overall GPA, so my main concern in this class is getting a good grade.
- 4) I want to do well in this class because it is important to show my ability to my family, friends, employer, or others.

Appendix 5

Course Evaluation Questions. All questions were Likert scaled from 1 (strongly disagree) to 5 (strongly agree). The question numbers refer to the question numbers shown in Figure 1. This survey was administered in each course section within the last two weeks of the semester.

- 1) My instructor is actively helpful when students have problems.
- 2) Mutual respect is a concept practiced in this course.
- 3) I feel free to ask questions in class.
- 4) My instructor deals fairly and impartially with me
- 5) When I have a question or a comment, I know it will be respected.
- 6) My instructor recognizes and rewards success in this course.
- 7) My instructor stimulates interest in the course.
- 8) My instructor makes good use of examples and illustrations.
- 9) My instructor has an effective style of presentation
- 10) This course has effectively challenged me to think.
- 11) My instructor holds the attention of the class.
- 12) The stated goals of this course are consistently pursued.
- 13) Exams stress important points of the lecture/text
- 14) Exams are reasonable in length and difficulty.
- 15) I am generally pleased with the text(s) required for this course.
- 16) My interest increased as the course progressed.
- 17) Overall, this course is among the best I have ever taken.
- 18) Overall, this instructor is among the best I have known.