

GENERAL CHEMISTRY TOPIC COVERAGE (GCTC) COMPARISON BETWEEN
COMMUNITY COLLEGES AND UNIVERSITIES IN THE UNITED STATES

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This study is based on survey responses of 224 general chemistry instructors at United States (U.S.) community colleges and universities representing 46 states. The mean values of General Chemistry Topic Coverage (GCTC) score, developed by this researcher specifically for this dissertation study as a measure of course content, were statistically analyzed. The aim of this study is to answer five research questions: (a) Is there a difference in mean GCTC scores between U.S. community colleges and four-year colleges and universities? (b) If there is a difference in mean GCTC score between the two study groups, what are the observed differences in subtopics covered between community colleges and four-year colleges and universities? (c) Considering both community colleges and universities, is there a difference in mean GCTC score between the different designated U.S. regions? (d) Considering both community college and university professors, is there a difference in GCTC score for professors with a master's degree compared to those with a doctorate?, and (e) Is there a correlation between GCTC score and the percentage of students that major in science?

Results indicate that there is a statistically significant difference in course content between community colleges and universities, there is a statistically significant difference between different U.S. regions, there is no statistically significant difference between professors with an earned master's versus those with an earned doctorate degree, and there is no statistically significant correlation between general chemistry course content and the percentage of a professor's students majoring in science. Details of the observed differences between community college and university course content are discussed, and recommendations for future research are presented.

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Amina Khalifa El-Ashmawy

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CHAPTER 1

INTRODUCTION

Overview

The American higher education system has its roots in the educational institutions of Western Europe, but it has adapted itself in many ways to the peculiar social, economic, political and cultural needs of its own society. This adaptation led to the creation of the two-year or junior college in the early twentieth century. The main driving force for the two-year college's inception was to relieve universities from having to teach the lower division courses and allow them to focus on upper level education and research. Over the past century, the junior college experienced much growth and change, including a change to a different name that reflected its evolution into a multipurpose institution: community college. The number of community colleges has grown tremendously. According to the American Association of Community Colleges (AACC) (2006a), there were a total of 74 community colleges in 1915-16, 207 in 1921-22, 678 in 1960-61, 1231 in 1980-81, and about 1600 in 2002. More recently, the number of colleges has not increased by much, but their enrollments have significantly increased. Community colleges now operate in all 50 states and enroll half of the students who begin college in the United States (Cohen & Brawer, 2003).

Despite the varied functions and perceptions, community college scholars agree that the American community college has its foundation in the transfer function. The institution's original function was to serve as a middle ground between high school and the university, but today serves the functions of transfer, vocational/technical education,

developmental education, economic development, and community service (Cohen & Brawer, 2003). Educational services besides transfer mainly started in the late 1940s when servicemen were returning home from military service and needed job training skills. According to the 1989–90 “Beginning Postsecondary Students Longitudinal Study” conducted by the U.S. Department of Education’s National Center for Education Statistics (Bradburn & Hurst, 2001), there are several definitions one can use for transfer rate. The authors reported that among 1989–90 beginning postsecondary students enrolled at public two-year institutions who transferred to four-year institutions by spring 1994, almost 95% expected to complete bachelor’s degree or higher. It was reported in 1998 that 40% of first-time, beginning community college students transferred to a four-year college or university (American Association for Higher Education [AAHE], 1998; National Center for Education Statistics [NCES], 2006a). The *2000 Digest of Education Statistics* published by the U.S. Department of Education (2002) cites that 58% of community college students are women and 26% are underrepresented minorities. Additionally, between 1989-90 and 2003-04 there was a 32.4% increase in number of associate degrees in the physical sciences and science technology and a 42.2% increase in number of associate degrees in the biological and biomedical sciences. This compares to 12% increase in number of bachelor degrees in the physical sciences and science technology and 65.3% increase number of bachelor in biological and biomedical sciences over the same period. These figures highlight the community college as fertile ground for growing the science and technology workforce (NCES, 2006b; 2006c).

The accrediting body under which a college or university falls dictates faculty credentials at higher education institutions. There are six accrediting bodies in the U.S.: Western Association of Schools and Colleges, Southern Association of Colleges and Schools (SACS), North Central Association Commission on Accreditation and School Improvement, New England Association of Schools and Colleges, Middle States Association of Colleges and Schools, and Northwest Commission on Colleges and Universities. These six entities all have basically the same criteria when it comes to faculty credentials. When it comes to the general chemistry course, the minimum faculty credential required by the accrediting agencies is a master's in or 18 graduate hours in the teaching discipline (SACS, 2001).

General Chemistry is a foundation or *gatekeeper* course (Hoyt, 1998) taught at most United States community colleges and universities. It “serves a diverse clientele—from chemistry majors through engineers and pre-health professional to liberal arts majors fulfilling a science requirement” (“The Forum,” 1992). Students seeking baccalaureate degrees in the mentioned majors need to take general chemistry (Gillespie, 1997); hence, it is offered predominately as a transfer course at the community college. The large number of students who take general chemistry makes the content of this course of great importance to the quality of undergraduate education nationally. It subsequently affects the matriculation of graduate students as well.

Statement of Problem

General chemistry courses are taught at both community colleges and universities making evaluation of course content essential. No national comparative

study of general chemistry course content between community college and universities has been found in the literature. The only comparative study similar to this one currently under investigation was reported in 1969 and was limited to one state (Denney, 1969). General chemistry is known as a *gateway course* for many students enrolled in post-secondary studies since course completion is required for most students majoring in science, engineering and pre-professional majors who plan to matriculate to post-baccalaureate studies. Approximately half of all chemistry students in the U.S. are enrolled at community colleges (Ryan, Neuschatz, Wesemann, & Boese, 2003). In several states (e.g., Colorado, Florida, Illinois, Iowa, Minnesota, Nevada, North Dakota, Pennsylvania, Texas, and Washington), there are common course numbers assigned to general education courses, which include general chemistry.

Purpose of Study

Community, junior, and technical colleges serve about half of all chemistry students each year in the United States (Ryan, Neuschatz, Wesemann, & Boese, 2003). Since mostly freshmen and sophomore level courses are offered at the two-year college, it is highly likely that more than half of the students taking general chemistry do so at a two-year college. Since general chemistry is a critical course for all science and engineering programs as well as most professional programs (e.g., pre-medical, pre-dental, pre-veterinarian, etc.) (Gillespie, 1997; "The Forum," 1992) it is important that courses taught at two-year colleges be the same in content as those taught at universities. Based on the argument posed so far, the content of general chemistry courses has been and will probably continue to be an important issue. Moreover, with

the large percentage of students taking the course at a community college, it is equally important that the content be comparable across the various types of institutions where the course is offered.

There is no established measure for course content found in the literature. For the purpose of this study, a specific measure, called *General Chemistry Topic Coverage* (GCTC) score, was developed and will be fully defined later in this chapter as well as described fully in subsequent chapters.

Research Questions

Given that two-year colleges require faculty to have a master's degree (with 18 graduate hours in teaching discipline) whereas universities require a doctorate or very specialized post-baccalaureate education (American Chemical Society [ACS], 2003; SACS, 2001), general chemistry course content possibly could be affected by this difference in professional training. Consequently, with the variety of academic majors that require students to take this course, many students' majors at an institution could perhaps be affected by the general chemistry course content as well.

The questions that this study addressed were:

1. Is there a difference in course content, measured by mean GCTC scores, between U.S. community colleges and four-year colleges and universities?
 - 1.1. If there is a difference in mean GCTC score between the two study groups, what are the observed differences in subtopics covered between community colleges and four-year colleges and universities?

2. Considering community colleges and universities, is there a difference in mean GCTC score between the different designated U.S. regions?
3. Considering both community college and university professors, is there a difference in GCTC score for professors with a master's degree compared to those with a doctorate?
4. Is there a correlation between GCTC score and percentage of students that major in science?

Significance of the Study

The last general chemistry course content study found in the literature was conducted in 1993 (Taft, 1997) and was limited in that it did not consider a critical player, the community college. The data collected for the study presented herein include both community colleges and universities from equally distributed regions of the United States. Hence, this study is more global in scope than previous studies with survey respondents being more indicative of the overall population than previous studies. As a result, this work can serve as a national baseline for future research.

The aim of this work is to gain insight on the possible factors that affect general chemistry course content, namely, institution type, professor's credentials, and percentage of students majoring in science. An important aspect is to evaluate whether or not both types of institutions are giving the *same* quality instruction, in order to avoid monumental differences between community college and university students.

This research will be of value for (a) helping students make choices about their science education, (b) professional school admissions officers to better assess an

applicant's transcript as it pertains to general chemistry, (c) general chemistry instructors who wish to fine tune and align their curriculum according to national trends, and (d) general chemistry textbook authors and publishers who have to balance what should be included and what can be eliminated in order to minimize textbook cost.

Abbreviations and Definitions

In this study on general chemistry content at community colleges and universities, the following terms and abbreviations will be used:

AACC: Association of American Community Colleges

AAHE: American Association for Higher Education

ACS: American Chemical Society

ACS Exam matrix: List of topics and subtopics tested on the ACS 2003 General Chemistry Exam

CI: confidence interval

Community College: Any and all United States two-year colleges including community, junior, city, county, branch campus, and technical colleges

CHEMED-Listserv: Chemical Education Listserv sponsored by ACS DivCHED

DivCHED: Division of Chemical Education of the American Chemical Society

Four-year college: See "university"

Four-year university: See "university"

GCTC score: General Chemistry Topic Coverage score; composite score that measures course content coverage, expressed as the number of ACS 2003 General Chemistry Exam subtopics covered by a professor; value score from 0 to 89

General chemistry: Foundation college course designed for science, engineering, and pre-professional medical field students

GPA: Grade point average

High stakes tests: Standardized secondary school exams used to measure student-learning outcomes; scores from these tests used for state funding of the public school district

Instructor: See professor

IRB: Institutional Review Board

NCES: National Center for Education Statistics

NEA: National Education Association

Pre-professional major: Includes but not limited to pre-medical, pre-dental, pre-pharmacy, and pre-veterinary

Professor: Survey respondents who teach in higher education regardless of title

Redox: Reduction-oxidation reaction

Retention rate: The percentage of students who re-enroll in the subsequent term until the educational goal is completed

SACS: Southern Association of Schools and Colleges

SD: Standard Deviation

SPSS: Statistical Package for the Social Sciences

STEM: Science, technology, engineering and mathematics

Subtopic: Specific items under the major content areas of the ACS 2003 General Chemistry nationally standardized exam

Topic: Major content area identified for the ACS 2003 General Chemistry nationally standardized exam of which there are ten

Transfer shock: A decline in the GPA after transferring from a community college to a university, often experienced in the first semester after transfer

Two-year college: See “community college”

University: Includes baccalaureate and higher degree-granting institutions in the United States and the District of Columbia

UNT: University of North Texas

CHAPTER 2

REVIEW OF LITERATURE AND CONCEPTUAL BASIS

The intent of the following review is to highlight the history and functions of the community college, the history and changes of high school science curriculum, and the purpose and content of the college general chemistry course as well as highlight the content emphasis changes over time. Summary of literature pertaining to the factors affecting success in general chemistry as well as general chemistry student misconceptions are also included.

History and Function of the Community College

The community college started at the beginning of the 1900s as the “junior college.” Its main focus was teacher education. According to Koos in his 1925 book, *The Junior-College Movement*, the four major purposes of junior colleges were: transfer, occupational programs, continuing education, and terminal general education programs. The enactment of the Government Issue (GI) Bill of 1944, which is officially known as the Servicemen’s Readjustment Act of 1944, brought significantly increased enrollment in higher education due to millions of veterans pursuing higher educational opportunities. The effects were transforming for the American colleges and universities. No longer was higher education for the well-born elite. Consequently, the community college underwent a shift in how it was viewed. This was also accompanied by a name change from junior college to community college. The community college then went

from playing a relatively minor role in American Higher Education to being a major force in the dynamics of modern higher education (Gleazer, 1963). According to the American Association of Community Colleges (AACC) (2006b), almost 50% of all students enrolled in the American higher educational system are at a community college. Moreover, based on data collected by the National Postsecondary Student Aid Study of 2003-04 the AACC found that “32 percent of community college students had previously attended a four-year university” (National Education Association [NEA], 2006).

At present there are more than 2000 community college campuses in the United States of America enrolling nearly 5 million students (Ryan, Neuschatz, Wesemann & Boese, 2003). In order to understand and to make its philosophy and concept clear, Gleazer (1963) described it well when he said:

A good community college will be honestly, gladly, and clearly a community institution. It is in and of the community. The community is used as an extension of classroom and laboratory. Drawing upon the history, traditions, personnel, problems, assets and liabilities of the community, it declares its role and finds this accepted and understood by faculty, administration, students, and the citizenry (p. 1).

With this description, one can better understand the present-day functions of the community college. The functions have been restated many times during the last seventy or eighty years. The most widely accepted of those is the list of functions put forth by Cohen and Brawer (2003), who make apparent the comprehensive view of the educational objectives of the community college in terms of the functions it serves (pp. 21-24):

1. Academic transfer: Academic transfer, or collegiate, studies were meant to fulfill several institutional purposes: a popularizing role, a democratizing pursuit, and a function of conducting lower-division courses for the universities.

2. Vocational-technical education: Vocational-technical education was written into the plans in most states from the earliest years.... Originally conceived as an essential component of terminal study—education for students who would not go on to further studies—vocational education in two-year colleges was designed to teach skills more complicated than those taught in high schools.
3. Continuing education: The continuing education function arose early as the community college evolved.
4. Developmental education: Developmental education, also known as remedial, compensatory, preparatory, or basic skills studies - grew as a percentage of students poorly prepared in secondary schools swelled community college rolls.
5. Community service: Early books on two-year colleges display a wide range of cultural and recreational events that institutions of the time were presenting for the enlightenment of their communities. Public two-year colleges adopted the idea as a useful aspect of their relations with the public, and special funds were set aside in some states for this function.

The above list of functions is a good illustration of the community college's uniqueness as compared to the secondary school and the university. Because the community college stands between these two segments of the educational system, the community college must serve the needs of students who intend to complete the requirements for a baccalaureate or higher degrees, and, at the same time, provide other needed educational services to a complex society.

Besides the functions mentioned above, Fields (1962) identified five fundamental characteristics that clearly establish the uniqueness of the two-year institution.

1. Democratic: Low tuition and other costs; nonselective admission policies; geographically and socially accessible; and popularized education for the largest number of people.
2. Comprehensive: A wide range of students with widely varying abilities, aptitudes, and interests; a comprehensive curriculum to meet the broad needs of such students.

3. Community centered: Locally supported and controlled; local resources utilized for educational purposes; a community service improving the general level of the community.
4. Dedicated to life-long learning: Educational programs for individuals of all ages and educational needs.
5. Adaptable: To individual differences among students, differences in communities, and the changing needs of society.

According to the Katsinas classification scheme (2003), community colleges can be grouped into three main types: urban, suburban, and rural. The ranking of Cohen and Brawer's (2003) functions varies with type of community college. However, its services are not confined exclusively to the traditional functions of the four-year colleges, but include activities that contribute to the general upgrading of society as a whole. The open door policy of the community college allows anyone to have access to higher education. Conversely, universities have entrance requirements assuring, to a certain degree, that students are more adequately equipped to succeed. The difference in admission requirements of the two types of institutions has led to a common perception that education obtained at community college is inferior as compared to university education.

History of High School Science and Chemistry Curriculum

In the 1950s before Russia's *Sputnik* was launched, the U.S. population viewed the physical sciences as merely a string of facts that are to be memorized rather than concepts that must be understood (DeBoer, 2001). With *Sputnik*'s launch came a realization by U.S. politicians and educators that the country was behind in the global race in science and mathematics. The National Science Foundation (NSF) was spurred

to fund initiatives that would elevate the U.S. globally in these areas (National Aeronautics and Space Administration[NASA], 2003; Welch, 1979). The public school science curriculum began focusing on what was being taught and how. In 1956 G. Zacharias, a Harvard physicist, got together with educators, scientists, and learning theorist to develop a new physics course (Howes, 2002). This group was known as the Physical Science Study Committee (PSSC). The resulting physics course was based on a “coherent set of related concepts” (Rutherford, n.d.).

During the same time period, there was an initiative by science educators at Reed College to develop a high school introductory chemistry course with a logical thinking focus that somewhat paralleled what the PSSC was doing. The project they developed was known as the Chemical Bond Approach (CBA). Howes quotes Lacy’s 1966 *Guide to Science Teaching in Secondary Schools* about CBA: “The concept that chemical bonds are the electrical-energy links that hold matter together, known as a CHEMICAL BOND, was the central theme” (p. 42).

The NSF sponsored a project in 1960 that was designed by high school teachers, university professors and industrial chemists called CHEM Study. “One of the more important goals of this study course was to give students a better idea of the nature of scientific investigation by emphasizing the ‘discovery approach,’ and that the laboratory was to be an essential part of the development of that goal” (University of Southern California [USC], 2003a).

Through the various NSF-funded curriculum projects, teachers were trained to use the particular approach. They, then, went back to their schools and worked with their principals to engage and train other teachers. Outcomes of these projects included

various ancillary materials. However, as per D. S. Mason the greatest significance of the 1960s curriculum development projects was the birth of hands-on/inquiry methods and the team approach to teaching (personal communication, Spring, 1991).

In the 1970s the fervor associated with the curriculum reform movement of the 1950s and 1960s had waned. Accordingly, NSF pursued information about the status of elementary and secondary (K-12) science education. N. Harms synthesized and interpreted the information gathered by NSF and provided a description of the actual status of K-12 science education in a monograph titled *Project Synthesis* (USC, 2003b). It established four goals or outcomes addressing personal needs, societal issues, academic preparation and career education, and awareness. *Project Synthesis's* major theme became science literacy for the general public (McCann, 1997). From *Project Synthesis* stemmed the science-technology-society (STS) movement. This interdisciplinary approach allowed the student to relate science, technology, and society through their natural, artificial, and social surroundings. The student could relate to science concepts through everyday life experiences (Lisowski, 1985).

F. J. Rutherford initiated Project 2061 in the 1980s. The premises of Project 2061 were: the ends come first, less is better, nothing is simple, and teachers are central. Project 2061 offered a set of recommendations presented in the form of basic learning goals. It spelled out the knowledge, skills, and attitudes all students should acquire as a consequence of their total school experience from kindergarten through high school (Ahlgren & Rutherford, 1993).

In the 1990s, NSF funded a project to create high school science curriculum that was based on National Science Education Standards (NSES) A Framework for High

School Science Education. This project involved science teachers, science education faculty, and professional scientists developing student materials as well as teacher materials for modules in biology, chemistry, earth and space science, and physics. These materials were revised yearly according to feedback received from students and teachers. Contrary to the previous approaches, this approach was driven from the bottom up (The National Health Museum, 2005).

In the late 1980s the American Chemical Society (ACS) produced a high school chemistry textbook called *Chemistry in the Community* (*ChemCom*), currently in its fifth edition. The following is a description of the *ChemCom* approach and textbook according to the W. H. Freeman Website:

Designed for a year-long high school chemistry course geared for college-bound students, *ChemCom* covers traditional chemistry topics with coverage organized around societal issues. With this program, students learn more organic and biochemistry as well as environmental and industrial chemistry. The text is 50% laboratory-based, with lab activities are fully integrated within context, not separate from the reading. *ChemCom* features decision-making activities to give students practice in applying their chemistry knowledge in various problem-solving situations. This text clearly addresses the fundamental concepts and principles found in the National Science Education Standards. Correlations are available showing how closely aligned *ChemCom* is to these and other state standards (ACS, 2005).

Purpose of the High School Chemistry Course

Stone addressed the high school chemistry course function in the early 1920s (Stone, 1924). He pointed out that only 10% of high school chemistry students matriculate to college chemistry. He concluded that “[t]he time has come when a course can be given in which both college requirement and the needs of the ninety per cent can be fairly met—a time when we need no longer deny to our great body of students such

instruction in the chemistry of the local industries as shall enable them better to understand their environment and the means by which it can be controlled” (Stone, 1924, p. 58). The sparse literature addressing the benefits of high school chemistry to college students began in the 1950s (Brasted, 1957; Carlin, 1957; Hadley, Scott & VaLente, 1953; Laughton, 1957). Researchers have reported (Deters, 2003, Keller, 1998) that the two schools of thought as to the purpose and content of high school chemistry are:

- (i) high school chemistry is preparation for college-level chemistry, should contain introductions to essentially the same topics taught in college chemistry, and should consist of the students that are recommended for the class or that show interest and potential in science-related careers or
- (ii) high school chemistry is a general-education course that should provide another way for students to view the world and further interest them in science; therefore, the course should be open to all students and focus on broad conceptual understanding. The high school teachers belonging to the second group do want their students to be prepared for college-level chemistry, however, this is not their only goal (Deters, 2003, p. 1153).

Deters (2003) surveyed a wide variety of college instructors of large institutions asking them to choose the top five topics from a list that they think students needed to master to promote success when taking a college general chemistry course. She found that the seven most chosen topics by college instructors were basic skills (units, significant figures, graphing, etc.), moles (molar mass), dimensional analysis (factor-label method), stoichiometry, naming and writing formulas, atomic structure (parts of an atom, electron configuration), and balancing equations. Deters also noted:

many professors stated that the topics, concepts, and knowledge students bring into college chemistry are not as important as the attitudes, process skills, and study skills. Comments [by the survey respondents] suggested that professors would rather have students with good study habits, without fear of chemistry, and an appreciation for how chemistry affects their everyday lives (Deters, 2003, p. 1154).

Mitchell conducted a study in late 1986 where he asked both high school teachers and college chemistry instructors what chemical knowledge, skills, and attributes they felt students should have in order to be successful in college chemistry. The results of his study were published in two parts (Mitchell, 1989; Mitchell, 1991). His findings were that high school teacher and college instructor perceptions about what is essential knowledge for students taking college chemistry differ. High school teachers feel it important to teach chemistry content so that students are exposed to it before going to college. This results in the high school course being more like a watered down college course. Conversely, “[h]igher level instructors prefer that lower level instructors concentrate on teaching students how to study and think in general, leaving the development of a specific knowledge base about the subject to the ‘experts’” (Mitchell, 1989, p. 564).

Dowdy (2005) found that secondary science teachers who did their collegiate work at two-year and four-year institutions felt about the same toward science, but the more science courses that a practicing teacher took at a two-year college the more favorable impression of science the teacher had.

Purpose and Content of the College General Chemistry Course

This section contains a review of the literature that addresses questions posed by Ferguson in 1924.

When a course is to be introduced into the high school, or for that matter into any other educational institution, the first question to ask is, why should such a course be offered? What are its objectives? What is to constitute subject matter? (p. 183).

Three objectives of the general chemistry course are found in the literature. They are to prepare students for further studies in the sciences (Gillespie, 1997; Mitchell, 1993), provide an understanding of the day-to-day usage of chemistry in fields other than science, such as engineering and pre-health professional (Gillespie, 1997; Hawkes, 1989; Mitchell, 1993; Treblow, Daly, & Sarquis, 1984), and elevate the scientific literacy of our citizenry with the basis for evaluating knowledge claims in the media (Forster, 2006; Mitchell, 1993). General chemistry is often “the only chemistry course a student takes and this will have an impact on the long-term education of the student” (Mitchell, 1993, p. 227). Brooks (1977) suggested that at larger universities different purpose or tracks of general chemistry can be distinguished by student cognitive level. “It seems to me that the basic objective is to be able to somewhat challenge the most intellectually capable students without being punitive to the least capable” (p. 655).

General chemistry course content has been a topic of interest since the 1920s. Cornog and Colbert (1924) conducted a study to formulate “a knowledge of what is now being taught” (p. 31) in freshmen chemistry courses. The data collected were from a questionnaire given to course teachers at 27 institutions, a review of widely used textbook content and of content of final exam questions. The majority of respondents indicated that they stressed theory more than facts and that there is too much taught in the course. Analysis of the textbooks’ content showed a total average of 70% descriptive chemistry and 30% theoretical matter. Out of the total 1834 final exam questions analyzed for content, 36.2% were equations and problems, 26.3% were descriptive, 23.5% were theory, and 13.8% were useful applications.

Through the 1950s the majority of the general chemistry courses taught in ACS-approved university chemistry programs can be described as “a very elementary study of physical-chemistry principles with such descriptive chemistry material as is necessary to understand the principles” (Lloyd, 1992, p. 634). Meloy’s (1954) found that 15% of class time was spent on metals, nonmetals, and their compounds, 3.5% of the time was spent on organic chemistry; 35% of the institutions did not include qualitative analysis in their course.

Nechamkin (1961, p. 255) carried out a study “to determine what college teachers believe is the course content of general chemistry.” The Director of General Chemistry at selected institutions was asked to indicate the importance of 230 items or topics selected from textbook indices based on a scale rating from A, being essential for inclusion in the course, to E, being unnecessary and should be omitted. Each categorical response was converted to a numeric score, and the total for each item or topic was tabulated and reported. Jones and Roswell (1973) duplicated the study and compared findings with those from the Nechamkin study. The seven topics that were rated unnecessary and should be excluded from course in Jones and Roswell’s study were: Acheson process, case hardening, air conditioning, meson theory, cellulose products, mineral names, and dyes. Seventy-one topics were rated as unimportant compared to 20 from the previous study. More theoretical topics, such as entropy, free energy, quantum numbers, and Pauli exclusion principle, were rated higher in importance than in the previous study while descriptive chemistry topics, such as zinc, sulfur, phosphorus, and iron chemistry, were rated lower in importance than in the previous study. Additionally, Jones and Roswell (1973) reported that 75% of the

institutions studied were on semester term system with more of the larger institutions being on the quarter term system, 75% offer qualitative analysis in the general chemistry course, and 76% offer quantitative analysis as a separate course.

Brooks (1977), in the first paper in a series of papers addressing the status of general chemistry, thought that descriptive chemistry is more relevant in the 1970s than it was in the late 1950s. He declared that there was surprising unanimity in the primary general chemistry course content—that included theoretical concepts, and he made the prediction that due to the energy crisis of the time there would be greater emphasis on energy in the near future.

Taft, of Educational Testing Service, conducted a study to determine the curriculum of colleges and universities that typically receive large numbers of advanced placement (AP) students in order to determine the appropriateness of content and level of difficulty of the AP chemistry exam given to high school students (1990). She surveyed 114 faculty teaching the general chemistry course at college and university chemistry departments receiving ten or more AP chemistry students per year.

The questionnaire was developed with three principal components in mind. First, it sought to determine the relative emphasis on the major topics included in the college curriculum for general chemistry. In addition, the survey sought to obtain more detailed information on inclusion or exclusion of specific subtopics within each major category (Taft, 1990, p. 241).

Taft's major findings were: "The college general chemistry course is crowded with respect to the number of topics it covers.... Topics in descriptive chemistry dominate the list for which 20% or more of respondents indicated no coverage in the college general chemistry course" (p. 247). Taft duplicated the study (1997) and reported, compared to the earlier study,

the findings indicate some change in emphases away from physical chemistry principles towards more 'relevant' chemistry of 'every day living' [such as environmental chemistry, chemistry of materials and polymers,] and support the hypothesis that recent curriculum reform initiatives in this direction have begun to take effect (p. 599).

Although she points to the emphases shift noticed, she states that these changes were minor.

Spencer (1992, 2006) and Gillespie (1997) addressed the recurring theme of too much course content in general chemistry. Spencer (1992, p. 183) asserts "there are only a few basic tenets of chemistry that encompass most of general chemistry. These are the laws of conservation of atoms and energy, the entropy law, and bonding." He adds that chemistry should be taught as a method or process rather than a collection of facts. Spencer listed calorimetry, Gibbs free energy (ΔG), phase diagrams, solubility product constant (K_{sp}), atomic spectra, quantum mechanics, colligative properties, Schrödinger equation, Clausius-Clayperon equation, and LeChâtelier's principle as topics that should be carefully considered before being taught. These topics are quite complex and could be taught provided we are willing to spend more time on them, at the cost of other topics, in order for students to truly understand them. The topics that Spencer feels might be better taught in a later course included molecular orbital (MO) theory, hard/soft acids-bases, statistical thermodynamics, and metal carbonyls and the effective atomic number rule. Balancing redox equations, extended buffer calculations, metal clusters, valence bond theory of complexes, geometrical isomerism of coordination compounds, and delocalization and shapes of MOs are among the topics Spencer feels are not necessary for general chemistry.

Gillespie (1997) presents perhaps more intriguing view of general chemistry content than Spencer. Gillespie proposes a general chemistry course based on six “great ideas of chemistry,” (p. 862) which are: atoms, molecules, and ions; the chemical bond: what holds atoms together in molecules and crystals; molecular shape and geometry: three-dimensional chemistry; kinetic theory; chemical reaction; and energy and entropy. He goes beyond previous claims of the crowded course content and gives the following major problems of the general chemistry course: “too much material; too much emphasis on abstract theory and not enough on reaction chemistry; no time for updating the course with new, more relevant material such as environmental chemistry, materials science, macromolecules and polymers, and biochemistry” (p. 864).

The ACS (1997, 2003) guidelines for first year courses are very general and do not provide much insight. However, the curriculum tends to be driven by the standardized exams that are published by the ACS Examinations Institute.

Factors Predicting General Chemistry Performance

Researchers have studied the effects of many factors specifically on general chemistry student performance. Such research appeared in the literature as early as the 1920s. Studied factors include high school chemistry grade, high school mathematics grades, aptitude test scores, mathematical aptitude test score, Piagetian criteria, manipulative Piagetian tasks, placement tests, and even psychological personality type.

Two studies from the 1920s were conducted by placing students in one of four groups based on factors being tested and comparing their quartile placement with performance in general chemistry. Scofield (1927) devised a three-part placement test

that tested student mathematics and chemistry knowledge and ability. Students were sectioned into four groups based on their test score. He then looked for correlation between student ability and course grade. He concluded that high school mathematics and chemistry grades as well as performance on the placement test are good predictors of course grade. Smith and Trimble (1929) sectioned students according to performance on aptitude or placement exams and monitored their performance in college chemistry course. They found that the best and poorest students' performance correlated with aptitude test scores. However, aptitude test scores for mid-level students did not show a strong correlation with course performance.

There is not complete agreement as to which predictor of general chemistry success is best. However, Scholastic Aptitude Test (SAT) Math score was found to be a good predictor of general chemistry course performance (Bentley & Gellene, 2005; Keller, 1998; Ozsogomonyan & Loftus, 1979; Pickering, 1975; Spencer, 1996). Kunhart, Olsen, and Gammons (1958) found that high school chemistry along with high school algebra grades were good predictors of students' success of two-year college students in the first year chemistry course. Keller (1998) found that completion of any level of high school chemistry did not correlate with college chemistry performance. Coley's (1973) study sought to

find the best predictor or combination of predictors which could be used to predict the student's probability of success or failure in general college chemistry courses provided in a community junior college and to derive expectancy tables for values determined from multiple regression equations designed to aid counselors in guiding students toward a choice of appropriate academic goals (p. 613).

Accordingly, Coley's independent variables were preparatory chemistry course, Toledo Chemistry Placement Examination (TCPE), American College Testing (ACT)

scores (composite, mathematics, natural science, English, social science), high school chemistry and algebra courses. The dependent variables were first-semester chemistry course grade and ACS General Chemistry Exam score. The results indicated that taking a preparatory chemistry course is the best predictor followed by TCPE score. He also found that ACT scores correlate with freshman grade point average (GPA) rather than with the specific course grade and recommends that each institution determine its own unique regression coefficients. His concluding statement reads: "Based on the total variance determined by each predictor variable, there is something else that contributes to success in chemistry. It may or may not be academic in nature, however, it is very significant!" (1973, p. 615). Mason and Mittag (2001) reported that there is a strong correlation between grades in general chemistry and the mathematics level completed for both students of Hispanic descent and other ethnicities.

Heeding Coley's advice that there might be a non-academic predictor of performance, let's turn to Clark and Riley's (2001) study of the connection between an individual's psychological personality type and success in freshman chemistry. Their study involved surveying 407 general chemistry students who were enrolled in the sections for science, engineering, and premedical majors to determine their Myers-Briggs personality type as well as the 23 faculty members of the Middle Tennessee State University chemistry department. These personality types were compared to course score. Results of this study were quite interesting. None of the 23 faculty members exhibited the "extroverted-seeks to inspire others" (p. 1410) personality type. Students with this personality type scored lowest in the course. Conversely, the high-

achieving students were categorized as introverted, thinking, and judging types; ten of the 23 faculty also demonstrated this same personality type.

The high-achieving students demonstrating these personality traits would be described in laymen's terms as (i) being most comfortable and productive studying by themselves, (ii) recognizing a chemistry class as being very beneficial to their goals, (iii) being very comfortable handling abstract ideas, (iv) preferring to reach conclusion based on mathematical and logical deductions, and (v) being well organized and punctual in completing studious tasks (p. 1410).

Clark and Riley's study implies that personality is a factor in college performance.

Perhaps this observation might have been what Coley was suggesting in 1973.

Herron (1975) studied the use of Piagetian tasks for student placement in Purdue University chemistry courses. An example of the tasks, Herron provided students with a set of colorless, odorless known solutions, and ask them to mix them in such a way as to produce a colored solution. He found a correlation of 0.8 between performance on the Piagetian tasks and the total points earned in his Purdue chemistry courses. Clearly, performance on the Piagetian tasks is a good predictor of success. Albanese et al. (1976) at the University of Nebraska – Lincoln also conducted a study of Piagetian criteria as predictors of student success in general chemistry. However, Albanese et al. studied the correlation between a paper-and-pencil placement test and course performance. The researchers found that their placement test showed very little variance in course performance. Other findings of their study included that chemistry majors scored significantly higher on the algebra formulation subscale of the Toledo Test than did other students in the course. This finding is in agreement with those of other researchers.

Because the students who take general chemistry courses come from a wide range of social and educational backgrounds, some chemistry departments have been

interested in identifying at the beginning of the semester those who are at risk of failing. Predictors of at-risk students studied include pre-semester assessment, Chemistry Aptitude Test score, Toledo Achievement Test, Group Assessment of Logical Thinking (GALT), mathematics SAT score, and high school chemistry. Pre-semester assessment was found to be a good predictor as was the Toledo Chemistry Achievement Test (Wagner, Sasser, & DiBiase, 2002). Hovey and Krohn (1958) reported that when considering the Toledo Chemistry Achievement Test score in combination with the Iowa Aptitude test score there was a strong correlation with performance in general chemistry. Martin (1942) reported that there was a significantly higher percentage of failure among students who had not had high school chemistry than among students who had high school chemistry. Having or not having taken high school chemistry is a predictor for risk of failure but not for success, as previously mentioned. Bunce and Hutchinson (1993) argued that although mathematics SAT score is a good predictor of success, it is difficult for an instructor to obtain. Instructors may not have access to information (or information may not be available) such as SAT scores that may not be required by an institution for admission. The GALT test is easy to administer in class and is a fairly good predictor that can serve as an “early warning device to alert both parties to the need for early intervention designed to help assure success in the course” (Bunce & Hutchinson, 1993, p. 187).

Student Misconceptions in General Chemistry

When students walk into their first general chemistry class they bring with them a wide range of ideas and conceptions from their previous education and from life.

According to the constructivist point of view, the student has either consciously or subconsciously constructed concepts that they build upon as they continue in their journey of education. Some of these conceptions are not consistent with the consensus of the scientific community and are called *alternate conceptions*. When the alternate conception negatively affects the student's learning it is called a *misconception* (Mulford & Robinson, 2002). If a student is exposed to information in the general chemistry course that is inconsistent with their already existing misconceptions, it is difficult for her or him to accept the new information.

Based on the implications in the literature, student misconceptions concerning chemistry topics can be caused by teacher comments or teacher misconceptions that are transmitted to the students (Gabel, Samuel & Hunn, 1987; Özkaya, 2002; Özmen, 2004; Sanger & Greenbowe, 1999; Tomlinson, Dyson, & Garratt, 2001). Azizoglu, Alkan, and Geban (2006) conducted research to determine what misconceptions about phase equilibrium pre-service chemistry teachers hold after instruction. They conclude with the following: "The fact that the subjects holding these misconceptions are pre-service teachers makes the findings remarkable. Teachers should themselves possess a sound understanding of science concepts before they help students learn these science concepts" (Azizoglu, Alkan & Geban, 2006, p. 952). Additionally, chemistry textbooks have been reported to be a source of student misconceptions (Garnett & Treagust, 1992; Ogude & Bradley, 1994; Sanger & Greenbowe, 1997; Sanger & Greenbowe, 1999). Sanger and Greenbowe (1997, 1999) and Garnett and Treagust (1992) studied electrochemistry misconceptions. They reported that students have 32 common electrochemistry misconceptions. The results of their studies confirmed other

findings (Ogude & Bradley, 1994) and showed that authors of general chemistry textbooks use simplifications as well as vague or misleading statements and terminology that either cause or reinforce misconceptions. Such findings seem more problematic when one considers that 71% of first-year chemistry students are categorized as using the textbook in a deep or making connections manner (Pentecost, 2003).

Several researchers (Birk & Kurtz, 1999; Bodner, 1991; Boo, 1998; Furio & Calatayud, 1996; Gabel, Samuel, & Hunn, 1987; Mulford & Robinson, 2002; Nakhleh, 1992; Özmen, 2004; Peterson & Treagust, 1989) have studied misconceptions about molecular structure, bonding, and the particulate nature of matter ranging from high school to entering chemistry graduate students. Boo (1998) and Furio and Catalayud (1996) considered these misconceptions in high school students. Mulford and Robinson (2002) studied the results and application of a diagnostic instrument for first-semester college chemistry while Peterson and Treagust (1989) studied the diagnosis of misconceptions using a multiple-choice pencil-and-paper diagnostic instrument for high school. Peterson and Treagust found that their instrument was useful in evaluating students' understanding and identifying commonly held covalent bonding and structure misconceptions.

Birk and Kurtz (1999, p. 128) reported:

at the high school level, students seem to have no understanding of molecular structure and bonding. Either they are not intellectually prepared to deal with abstract topics like this, or they have poor learning experiences. Students in their first year of college begin to show some understanding, but many of them respond inconsistently to similar questions, revealing lack of comprehension. At the advanced graduate and faculty level, the misconceptions have disappeared for the most part, although performance is still not at 100%. A major difference between general chemistry students and advanced chemistry students is the

study of organic chemistry, which places considerable emphasis on bonding and molecular structure.

Researchers have studied misconceptions to a great degree. Peterson and Treagust (1989) point out that misconceptions continue to exist among students despite the great amount of research published in the literature, which, they say, is a sign that there is a gap between research and practice. The theory and knowledge about misconceptions are available, yet teachers and textbook authors seem to not be accessing this information. “The findings of this study should be applied in methods courses with pre-service and in-service physical science and chemistry teachers. Teachers need to be trained to diagnose students’ misconceptions...” (Yeziarski & Birk, 2006, p. 960). “Changes are also needed in chemical education, including chemistry curricula and textbooks, as well as teacher education programs” (Azizoglu, Alkan, & Geban, 2006, p. 952).

Community College Transfer

Student performance between Oregon two-year colleges and four-year universities was compared in Denney’s 1969 study. He concluded that there is no statistically significant difference between the community college and four-year university general chemistry students’ critical thinking ability. Additionally, there was no statistically significant difference found in the student knowledge of the fundamental facts and principles of chemistry between the two groups. One of the recommendations Denney made in 1969 is that community college transfer curriculum “be continuously evaluated and improved to assure the success of students beyond the fourteenth year” (Denney, 1969, p. 93).

The success of transfer students from two-year colleges to universities has been associated with various factors including high school chemistry preparation (Fowler, 1988; Keller, 1998), transfer shock (Harrington, 2000), and university culture (Nowak, 2004). Research shows that high school science teachers view their goal as imparting the skills and knowledge they believe are necessary for success in subsequent science courses (Deters, 2003). However, Keller (1998) found that there was no correlation between completion of any level of high school chemistry and academic performance in college chemistry.

In studying the effect of transfer shock on student performance, Harrington (2000) compared the GPA of North Carolina transfer students versus native students over a period of two years. Harrington also compared retention rates as well as graduation rates. Data gathered showed that there was no significant difference between the two populations in their overall GPA, but there was evidence that transfer students had transfer shock but were able to recover from this phenomenon. As for the retention rates, native students to the university seemed to have slightly better retention rates than transfer students. Harrington, however, asserts that the retention rates could stand improvement for both groups.

Faculty Background Characteristics and Activities

The following are credential guidelines for higher education institutions (Southern Association of Colleges and Schools [SACS], 2001, p. 25).

- a. Faculty teaching general education courses at the undergraduate level: doctor's or master's degree in the teaching discipline or master's degree with a concentration in the teaching discipline (a minimum of 18 graduate semester hours in the teaching discipline).

- b. Faculty teaching associate degree courses designed for transfer to a baccalaureate degree: doctor's or master's degree in the teaching discipline or master's degree with a concentration in the teaching discipline (a minimum of 18 graduate semester hours in the teaching discipline).
- c. Faculty teaching associate degree courses not designed for transfer to the baccalaureate degree: bachelor's degree in the teaching discipline, or associate's degree and demonstrated competencies in the teaching discipline.
- d. Faculty teaching baccalaureate courses: doctor's or master's degree in the teaching discipline or master's degree with a concentration in the teaching discipline (minimum of 18 graduate semester hours in the teaching discipline). At least 25 percent of the discipline course hours in each undergraduate major are taught by faculty members holding the terminal degree—usually the earned doctorate—in the discipline.
- e. Faculty teaching graduate and post-baccalaureate course work: earned doctorate/terminal degree in the teaching discipline or a related discipline.
- f. Graduate teaching assistants: master's in the teaching discipline or 18 graduate semester hours in the teaching discipline, direct supervision by a faculty member experienced in the teaching discipline, regular in-service training, and planned and periodic evaluations.

As noted above, the minimum faculty credential requirement is the same for faculty teaching undergraduate general education courses, whether they are at a community college or university. However, in practice, a very high percentage of faculty at baccalaureate and higher degree granting institutions has earned a terminal degree.

According to Zimble (2001):

In the fall of 1998, 67 percent of full-time instructional faculty and staff at postsecondary institutions had a doctoral or a first-professional degree (which includes medicine, dentistry, optometry, osteopathic medicine, pharmacy, pediatric medicine, veterinary medicine, chiropractic, law, and theological professions), 28 percent had a master's degree, and 5 percent had a bachelor's degree or less. A very small percentage of full-time instructional faculty and staff reported having earned no postsecondary degree. These individuals are included among those with "a bachelor's degree or less." Approximately 92 percent of full-time instructional faculty and staff at private not-for-profit research institutions had doctoral or first-professional degrees. In contrast, about 20 percent of the full-time instructional faculty and staff at public two-year institutions held such

degrees. Approximately 60 percent of part-time instructional faculty and staff at private not-for-profit research institutions had doctoral or first-professional degrees, whereas about 11 percent of the part-time instructional faculty and staff at public two-year institutions held such degrees.

More stringent requirements govern chemistry faculty credentials in order for a chemistry program to be ACS-accredited. These requirements are included in the *ACS Guidelines for Chemistry Programs at Two-Year Colleges* (ACS, 1997) and *Undergraduate Professional Education in Chemistry: Guidelines and Evaluation Procedures* (ACS, 2003) for universities. For two-year colleges a master's degree in a discipline of chemistry is the minimum academic preparation required. However, for universities,

[t]he scientific and educational capabilities of the faculty should be distributed over the major areas of chemistry so that upper-level and advanced courses are taught by persons qualified in each specialty. At least 75% of the faculty in chemistry must have a doctoral degree in the chemical sciences (ACS, 2003, p. 16).

Haworth (1999) presents two schools of thought on community colleges recruiting those with a doctorate (Ph.D.) for faculty positions. One school of thought is that a Ph.D. or terminal degree is an indicator of excellence. This degree carries designation with philosophical underpinnings that are brought into the classroom. The other school of thought is that teaching is the main focus and objective of a community college. Teaching experience and skill are more important than a terminal degree. Haworth also points out that many Ph.D.s apply for jobs at community colleges without knowing the expectations of the institution.

Faculty responsibilities extend beyond teaching and include research, administration, community and public service, clinical service, and technical activities. Almost one-third of full-time faculty at research universities indicated that their primary

activity was research compared to almost no full-time faculty at community colleges being engaged primarily in research. Full-time faculty in all of higher education spent an average of 11 hours per week actually teaching. The range was 7 hours for full-time faculty at private research institutions to 17 hours for full-time faculty at public community colleges (Zimbler, 2001).

Students, Preparedness, Majors, and Enrollment

Student success in postsecondary education is known to depend on high school education, among other factors. Warburton, Bugarin, and Nunez (2001) defined four curricular tracks in high school education ranging from basic core curriculum all the way up what they term the “rigorous” curriculum.

Core New Basics curriculum includes 4 years of English, 3 years of mathematics, and 3 years of science and social studies. Beyond New Basics I includes core New Basics and at least two of three science courses (biology, chemistry, or physics), and algebra I and geometry, plus 1 year of foreign language. Beyond New Basics II includes core New Basics, advanced science (biology, chemistry, and physics), and advanced math (including algebra I, geometry, algebra II), plus 2 years of foreign language. Rigorous includes core New Basics, advanced science (biology, chemistry, and physics), and 4 years of math (including algebra I, geometry, algebra II, precalculus), plus 3 years of foreign language and one honors/Advanced Placement (AP) course or AP test score (Warburton, Bugarin, & Nunez, 2001).

Warburton, Bugarin, and Nunez (2001) found there was a direct proportionality between the student’s high school curriculum rigor and their postsecondary GPA and an inverse proportionality between the rigor of a student’s high school curriculum and the number of developmental courses they took in the first year of their postsecondary education. Additionally, they found a strong correlation between academic rigor of their high school

curriculum and several factors including their rates of persistence towards and attainment of a degree, likelihood of remaining enrolled in postsecondary education.

According to the National Center on Education Statistics (NCES), student enrollment in colleges and universities is projected to continue increasing through 2015 (2006b). Additionally, they reported that there was a 33% increase in the number of bachelor's degrees awarded and 46% increase in the number of associate's degrees awarded between 1989-90 and 2003-04. During that same time period only the degree field of engineering and engineering technologies suffered a decline in enrollment (5%) while the other majors did not (NCES, 2006b; 2006c). Specifically, the number of awarded bachelor's degrees in biological and biomedical sciences increased by 65.3% and physical sciences and science technologies increased by 12% between 1989-90 and 2003-04. For the same time period, the number of awarded associate degrees in biological and biomedical sciences increased by 42.2% and physical sciences and science technologies increased by 32.4%.

Of all the 1999-2000 degree-seeking undergraduates 26.3% were in academic areas of study, 66.2% were in career areas of study, and 7.5% were in other areas of study (NCES, 2006c). The academic areas of study include English and literature, fine and performing arts, interdisciplinary studies, liberal arts and general studies, mathematics, science, and social sciences. The career areas of study included agriculture and natural, business and marketing, communications and design, computer science, education, engineering and architectural, health care, legal services, personal and consumer services, public, social and human services, and trade and industry. Of the academic degree-seeking undergraduates, 7% of the total majored in science, 1.8%

of the baccalaureate students and 8.9% of the sub-baccalaureate students majored in science (NCES, 2006c).

There was 37% of 1999 and 2000 physical science bachelor and master's degree recipients in the United States who had attended community college at some point in their higher education compared with an 44% average for all science and engineering degree recipients (Tsapogas, 2004).

In 1999 and 2000, almost half of the more than 740,000 S&E [science and engineering] graduates with bachelor's degrees attended a community college. About one-third of the nearly 161,000 graduates with master's degrees in S&E did so. Among recent doctorate recipients (1996–2000), slightly more than 8 percent reported that they had attended community college before receiving their doctoral degrees (Tsapogas, 2004).

Summary

Over the past several decades post-secondary general chemistry courses have been the subject of much research and discussion. There is a plethora of research done on factors predicting success and failure in general chemistry as well as student misconceptions. Topics in the literature on general chemistry span the scope from actual goals of the course to focus to student performance to content. Particularly in the 1970s there was a good deal of research dedicated to high school preparation and performance in post-secondary chemistry. The literature is saturated with published work in the area of student success predictors in general chemistry. However, there are areas of study where voids in the literature were noticed. There was no published study, whether localized or on a national level, within the past decade found in the literature addressing overall general chemistry course content. Moreover, there is no study found in the literature that addressed course content across types of higher education

institutions, for professors with different academic and professional preparation, or for student majors.

CHAPTER 3

METHODOLOGY

This chapter describes the experimental group and the selected studied sample. The experimental design and data collection methods are discussed. Also provided are demographics of the responding sample including average class size, percentage of students in science, engineering, pre-professional and other majors, average age of students in respondents' classes, breakdown of general chemistry faculty by gender and status in participating institutions as well as the textbooks used by a majority of the respondents.

Design

Because the intent of this work is to provide information of general chemistry course content, this study employed a descriptive design based on Internet collected survey data. The design is a simple quantitative approach and fairly straightforward to execute yielding important information to chemical education researchers and to the readers (Gall, Gall, & Borg, 2003).

Procedures

The study was conducted using a survey (see Appendix A) made electronically available through the Internet. B. Herrick (Colorado School of Mines) wrote the program for the Webpage as per specifications providing a means by which the collected data

could be accessed in spreadsheet format. The survey consisted of two parts. Several chemical education researchers contributed to the design of the survey items.

Additionally, Collin County Community College (CCCC) colleagues as well as CCCC students from the fall 2004 general chemistry classes tested the Website to insure perfect working order before the study was officially launched.

Part I consisted of items targeting selected characteristics of the responding sample population. The characteristics featured include the respondent's institutional affiliation, type of institution, entrance requirements, program faculty, textbook used, lecture format, average class size, breakdown of students' majors, and course attrition. Part II listed topics and subtopics (see Appendixes A and B) accepted nationally by chemical educators as the content of general chemistry courses. The topics and subtopics are those used in the American Chemical Society (ACS) 2003 General Chemistry standardized exam. The reasons for basing this study on the 2003 exam topics and subtopics was because that particular exam was the most current one published by the ACS Division of Chemical Education (DivCHED) Examinations Institute at the time of this work.

The study was conducted by collecting data through the electronic survey. Invitation to participate in the study was mailed through the United States Post Office to the target population. The ACS Education Division provided the mailing list of community college chemistry contact persons. It was a complete list of all community college chemistry departments. The University of North Texas (UNT) Department of Chemistry office provided the mailing list of university contact persons. (The mailing lists are available from the researcher upon request.)

Invitation letters (see Appendix C) were mailed on September 12, 2005 to chemistry faculty contacts at all 1,190 community college campuses with chemistry programs as indicated by the American Association of Community Colleges and to 568 university chemistry faculty contacts. Of the 1,758 letters mailed, only one was returned. Additionally, members and friends of the ACS DivCHED Committee on Chemical Educational Research received an electronic mail invitation to participate in the study on October 5, 2005. An invitation was also posted on the CHEMED-Listserv on October 25, 2005. The Listserv had 1,131 members signed on at the time of posting, 427 of which had an “.edu” email account. Members of this listserv are from all over the world; there were two non-U.S. respondents in the study. Only data obtained from U.S. respondents were used. By March 29, 2006 there were 226 valid survey respondents from 46 states. Given that respondents with either a master or doctorate-level education were to be considered in answering the third research question, the two respondents who had a bachelor’s degree were excluded from the analyses for consistency, which left 224 respondents that were considered for the study.

Sample

The population targeted was general chemistry instructors at U.S. community colleges and universities. Chemistry department chairs were also targeted since they possibly set and/or approve the curriculum for their department courses. The sample was self-selected because it consisted of chemical educators who chose to participate in this research study. Their completion of the survey represented evidence of their voluntary consent to participate in the study. UNT's Institutional Review Board (IRB)

approval was obtained (Application No. 04-401, Appendix C) to conduct this research as it is considered Human Subject Research.

Sample Demographics

A sample size of 224 was obtained for this study. Even though more data were collected, only 224 data points met the criteria of the study: respondents at a U.S. community college or university and had earned a minimum of a master's degree. The response rate was 11.3% (135 of the 1190 targeted) for community colleges and 15.7% (89 of 568 targeted) for universities. Of the total sample of 224, 135 (60.3%) were community college and 89 (39.7%) were university responses with geographic distribution from the different U.S. regions (see Figure 1 and Appendix D, Table A1). Regional distribution consisted of: 32 (14.3%) Western, 61 (27.2%) Central, 39 (17.4%) Eastern, 45 (20.1%) Southern, and 47 (21.0%) Southwestern. This distribution is provided for the purpose of documenting the *equivalent* distribution of the gathered survey data as well as to answer research question #2.

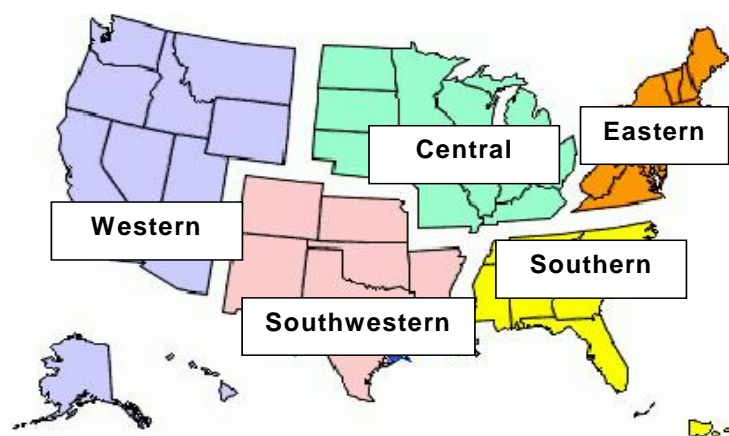


Figure 1. Sectional map of the U.S. regions used in this study (Office of Hazardous Material Safety, 2005).

The descriptive statistics for general chemistry faculty at participating institutions are presented in Tables 1 and 2. At participating community colleges, the mean number of general chemistry instructors (standard deviation) that are full-time female was 0.64 (*SD* 0.77), full-time male was 1.30 (*SD* 1.43), part-time female was 0.76 (*SD* 1.28), and part-time male was 1.43 (*SD* 2.74). At participating universities ($n = 89$), the mean number of general chemistry instructors that are full-time female was 1.19 (*SD* 1.34), full-time male was 3.07 (*SD* 2.83), part-time female was 0.23 (*SD* 0.43), and part-time male was 0.51 (*SD* 0.85).

Table1

General Chemistry Faculty Status and Gender at Participating Community Colleges ($n = 135$) and Universities ($n = 89$)

Faculty status and gender	Mean Number (<i>SD</i>)	
	Community college	University
Full-time female instructors	0.64 (0.77)	1.19 (1.34)
Full-time male instructors	1.3 (1.43)	3.07 (2.83)
Part-time female instructors	0.76 (1.28)	0.23 (0.43)
Part-time male instructors	1.43 (2.74)	0.51 (0.85)

For the total sample, the number (percent) of professors holding a doctorate and master's degree are 160 (71%) and 64 (29%), respectively. At community colleges ($n = 135$) there are 74 (54.8%) and 61 (45.2%) holding a doctorate and master's,

respectively, while at universities there are 86 (96.6%) and 3 (3.4%) holding doctorate and master's, respectively.

Table 2

Faculty Credentials at Participating Community Colleges and Universities (n = 224)

Institution type	Doctorate	Master's
Community College	74 (54.8%)	61 (45.2%)
University	86 (96.6%)	3 (3.4%)

Information about the textbook used by respondents was gathered. Brown, Le May, et al. is used by 41 (18.3%) of the respondents making it the most commonly used textbook of those listed (see Appendix A for list). The Chang textbook ranked a distant second place with 26 (11.6%) of the respondents using it, and Silberberg's textbook came in third place with 24 (10.7%) of the respondents using it.

Descriptive statistics for general chemistry students at participating community colleges and universities are presented in Table 3. For community colleges, the average general chemistry class size was 29.63 (*SD* 14.57), average general chemistry student age was 22.98 (*SD* 3.31), mean percentage of respondent's students majoring in science was 22.48 (*SD* 16.26), mean percentage of respondent's students majoring in engineering was 17.69 (*SD* 10.52), mean percentage of respondent's students majoring in pre-professional was 30.00 (*SD* 21.28), and mean percentage of respondent's students majoring in other fields of study was 20.90 (*SD* 18.09).

For universities, the average general chemistry class size was 90.17 (*SD* 91.00), average general chemistry student age was 20.72 (*SD* 2.19), mean percentage of respondent's students majoring in science was 39.51 (*SD* 25.55), mean percentage of respondent's students majoring in engineering was 18.98 (*SD* 17.02), mean percentage of respondent's students majoring in pre-professional was 29.80 (*SD* 18.75), and mean percentage of respondent's students majoring in other fields of study was 15.18 (*SD* 8.79).

Table 3

Descriptive Statistics for General Chemistry Students at Participating Community Colleges (n = 135) and Universities (n = 89)

Characteristic	Mean (<i>SD</i>)	
	Community college	University
Average class size	29.63 (14.57)	90.17 (91.00)
Average student age	22.98 (3.31)	20.72 (2.19)
Percentage majoring in pre-professional	30.00 (21.28)	29.80 (18.75)
Percentage majoring in science	22.48 (16.26)	39.51 (25.55)
Percentage majoring in engineering	17.69 (10.52)	18.98 (17.02)
Percentage majoring in other fields of study	20.90 (18.09)	15.18 (8.76)
Percentage that drops or withdraws from course	20.34 (13.06)	14.00 (9.00)
Percentage that take organic chemistry	21.18 (15.05)	46.84 (19.75)

Measures

Dependent Variable

General Chemistry Topic Coverage (GCTC) Score

There was no established measure for course content found in the literature. This author therefore developed the GCTC score as a quantitative measure on a continuous scale to facilitate data analysis. Because the subtopic content data collected were whether or not a respondent included each of the subtopics in their course, the author derived this measure by adding the total number of subtopics covered by the study participant. There were a total of 89 possible subtopics on the ACS exam matrix. Consequently, the GCTC score has a theoretical range of possible values from 0 to 89. Lower scores indicate fewer subtopics covered while higher scores indicate more subtopics were covered. Effect size, determined by Cohen's d , was calculated using the equation:

$$d = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{SD_1^2 + SD_2^2}{2}}},$$

where the \bar{X}_1 and \bar{X}_2 are the mean GCTC scores for the two study groups, and SD_1^2 and SD_2^2 are the variances for the two study groups' GCTC scores. "The denominator of this formula averages the variances (i.e., the square of the SD s) and then converts this average into a pooled SD via the square root" (Henson, in press).

Independent Variables

School Type

Survey data collected from the respondents were measured on a categorical scale. The type of school was categorized as either Community College or University.

U.S. Regions

The United States are divided into five geographic regions: Western, Central, Eastern, Southern, and Southwestern (Office of Hazardous Materials Safety, 2005). A listing of States in each region can be found in Appendix B.

Highest Degree Held

Survey data collected from the respondents were measured on a categorical scale. The instructors' highest educational degree held was recorded as Masters or Doctorate regardless of degree type or major emphasis.

Percentage of Students Majoring in Science

The percentage of students majoring in science was measured on an ordinal scale. The percentage of the instructor's students majoring in science was coded as a median representative percentage. For example, the percentages are 13% (for the 0-25% survey response), 37% (for the 26-50% survey response), 63% (for the 51-75% survey response), and 88% (for the 76-100% survey response).

Statistical Methods

All analyses were performed using the statistical package for social science software program SPSS for Windows® (SPSS 14.0, SPSS Inc., Chicago, IL). Both descriptive and inferential statistical methods were employed. All testing was based on determining statistical significance employing a two-tailed *t*-test ($p < 0.05$). The study sample was described using frequency and percentage for categorical variables and mean and standard deviation for continuous variables. A two-sample *t*-test was used to compare the average General Chemistry Topic Coverage (GCTC) score between two

groups: Community Colleges and Universities. A second two-sample t -test was used to compare the average GCTC score between two groups: Masters-degreed and Doctorate-degreed professors. Spearman's rho correlation was used to test for an association between the GCTC score and the percentage of the professor's students majoring in science (Hinkle, Wiersma, & Jurs, 2003). Chi-square tests were used to compare the percentage of professors who covered each subtopic between Community Colleges and Universities (Hinkle, Wiersama, & Jurs, 2003).

Delimitations and Limitations

The study was limited to content of college general chemistry yearlong lecture course as aligned with the ACS DivCHED's 2003 General Chemistry standardized exam that assesses didactic knowledge. The study utilizes information gathered about topic coverage, faculty credentials, and percentage of students majoring in science that was self-reported by survey respondents ($n = 224$). The sample includes general chemistry instructors or chemistry department chairs choosing to participate in the study making the sample one of convenience. The study does not include the sequence in which different topics were taught or the pedagogical approaches employed to achieve course objectives. The content, approach, and curriculum of laboratory or recitation components of the course were not considered. Lastly, the instructor's highest educational degree held was recorded as Masters or Doctorate with no distinction made for the discipline in which the degree was awarded.

The initial data collected included number of lecture periods the respondent spent on each topic as well as the length of their lecture periods. Since the data did not

total the expected number of lecture hours for a full course (approximately 90 hours), additional data were collected to assess the validity of the initial data. Due to failure in asking pertinent questions in the same manner both times, the second-round data did not prove to support the initial inquiry. Additionally, the initial and second-round questions collected inconsistent responses indicating that different individuals may not have interpreted the questions in the same way. Having collected reliable subtopic data from all respondents, the time spent per topic data was not used in answering the research questions.

CHAPTER 4

RESULTS AND DISCUSSION

The purpose of this study was to provide information about the content of general chemistry courses taught at U.S. community colleges and universities in order to determine whether the content is comparable across the various types of institutions that offer the course. Accordingly, general chemistry instructors at both types of institutions were surveyed to ascertain which of the American Chemical Society (ACS) 2003 General Chemistry Exam subtopics (falling under the ten topics: atomic structure, molecular structure, dynamics, equilibrium, stoichiometry, energetics, electrochemistry and redox (oxidation-reduction), descriptive chemistry and periodicity, states of matter and solutions, and experimental) they cover in their courses, their highest degree held, and the percentage of students taking their general chemistry course who major in the sciences.

The subsequent sections present discussion of General Chemistry Topic Coverage (GCTC) score and analysis and interpretation of results for each research question.

GCTC Score

The GCTC score was determined by totaling the number of ACS Exam subtopics covered by each respondent. The score can take on a value from 0 to 89, which is the total number of subtopics included in the ACS Exam matrix. A higher GCTC score

indicates greater amount of information included in a course. Conversely, a lower GCTC score indicates less information included in a course.

The average GCTC score and standard deviation (*SD*) for the sample ($n = 224$) was 75.83 (9.94) with a range of 40 to 89. The average GCTC score (*SD*) for community colleges in this study ($n = 135$) was 77.10 (8.71) with a range of 45 to 89 while that for universities in this study was 73.91 (11.34) with a range of 40 to 87.

Research Question 1

Research question 1 of this study is: Is there a difference in mean GCTC score between U.S. community colleges and four-year colleges and universities?

Figure 3 is an error bar chart that shows the average, at a 95% confidence interval (CI) for the average, GCTC score separately for Community College and University categories. The graph clearly illustrates that the average GCTC score was larger in the Community College group compared to the University group. In Table 4 the average GCTC score is seen to be statistically significantly larger in the Community College group compared to the University group. The average GCTC scores (*SD*) were 77.1 (8.7) and 73.9 (11.3) for the Community College and University groups, respectively ($t = 2.37$; $df = 222$; $p = 0.019$). Effect size was 0.3155, which is considered to be medium in effect (Becker, 2000; Thalheimer & Cook, 2002; Valentine & Cooper, 2003).

There is agreement that an effect size greater than 0.20 is of noteworthy effect in education research (Becker, 2000; Thalheimer & Cook, 2002; Valentine & Cooper, 2003). With a p -value of 0.019 the result obtained for this research question is

statistically significant. Additionally, the effect size of 0.3155 indicates that the mean community college GCTC score is almost one-third standard deviation higher than the mean university GCTC scores (Becker, 2000; Henson, in press).

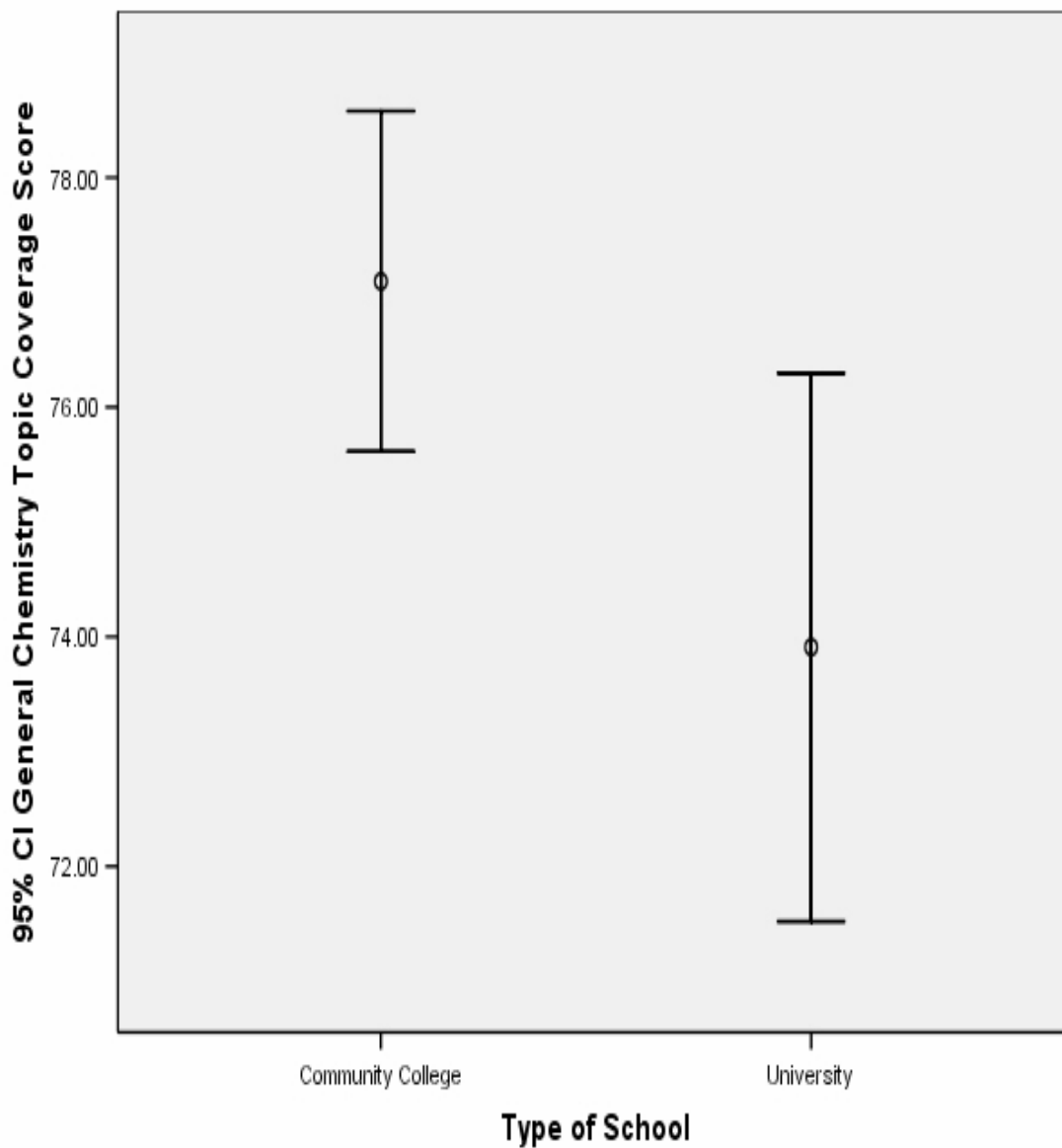


Figure 2. Error bar chart for type of school depicting GCTC scores for community colleges, $\bar{X} = 77.10$ (8.71), and universities, $\bar{X} = 73.91$ (11.34).

Table 4

GCTC Score Comparison Between the Two Types of Institutions

	GCTC Score		<i>t</i>	<i>df</i>	<i>p</i>
	<i>n</i>	Mean (<i>SD</i>)			
Community College	135	77.10 (8.71)	2.372	222	0.019
University	89	73.91 (11.34)			

Research Question 1.1

Research question 1.1 of this study is: If there is a difference in mean GCTC score between the study two groups, what are the observed differences in subtopics covered between community colleges and four-year colleges and universities?

All 89 subtopics were compared between community colleges and universities to determine if there was a difference in the percentage of respondents that covered the subtopics between the two groups. There was no statistically significant difference in the percentage of professors from community colleges and those from universities who cover 74 of the 89 subtopics. Only 15 of the 89 subtopics showed a statistically significant difference in the percentage of community college and university professors who cover them. Appendix E (Tables A2-A11) shows detailed results of all subtopic comparisons.

The subtopics that showed no statistically significant difference in coverage between the two study groups for the topic of *atomic structure* are: experimental basis, atomic symbols and isotopes, atomic mass, atomic spectra and Bohr theory, quantum theory, orbital (not hybrids) shapes and energies, and electron configurations.

The subtopics that showed no statistically significant difference in coverage between the two study groups for the topic of *molecular structure* are: nomenclature, Lewis structure, molecular geometry and Valence Shell Electron Pair Repulsion (VSEPR) theory, ionic bonding and crystal structures, covalent bonding and hybrid orbitals, electronegativity and polarity of bonds and molecules, bond order and bond strength, and metallic bonding.

The subtopics that showed no statistically significant difference in coverage between the two study groups for the topic of *dynamics* are: determination of reaction order, rate laws, half-lives, collision theory, temperature dependence and the Arrhenius equation, energy diagrams and catalysis, mechanisms, diffusion and effusion.

The subtopics that showed no statistically significant difference in coverage between the two study groups for the topic of *equilibrium* are: gaseous and heterogeneous, LeChâtelier's principle and equilibrium constant (K) versus reaction quotient (Q), precipitation and solubility product constant (K_{sp}), and common ion effect.

The subtopics that showed no statistically significant difference in coverage between the two study groups for the topic of *stoichiometry* are: mole concept, mass, mole and formula unit, empirical and molecular formula, balancing equations (not redox), net ionic equations, limiting and excess reagent, theoretical and percent yield,

solution stoichiometry (including titrations), stoichiometry and enthalpy, and stoichiometry and gases.

The subtopics that showed no statistically significant difference in coverage between the two study groups for the topic of *energetics* are: heat capacity, calorimetry, heat, work and energy, enthalpy and standard states, Hess's Law, heat of formation, phase changes and energy, entropy, and free energy and equilibrium.

The subtopics that showed no statistically significant difference in coverage between the two study groups for the topic of *electrochemistry and redox* are: oxidation numbers, oxidizing and reducing agents, balancing redox equations, galvanic cells: theory, use and interpretation of E° tables and activity series, Nernst equation, Gibbs free energy (ΔG), standard potential (E°), and K relationships, electrolytic cells and Faraday's Law, and electrochemical applications: batteries, corrosion and plating.

The subtopics that showed no statistically significant difference in coverage between the two study groups for the topic of *descriptive chemistry and periodicity* are: periodic trends, acidity, reactivity and metallicity, and predicting reaction products.

The subtopics that showed no statistically significant difference in coverage between the two study groups for the topic of *states of matter and solutions* are: general properties of gases, gas laws, general properties of liquids, intermolecular forces, concentration units, colligative properties, solubility principles and rules, solids and crystal structures, and phase diagrams.

The subtopics that showed no statistically significant difference in coverage between the two study groups for the topic of *experimental* are: use of equipment and

instrumentation, precision and accuracy, reparation and analysis of solutions, experimental design, interpreting data and graphs, and scientific method and ethics.

In order to gain insight as to where the differences in course content between the two study groups lie, we need to look at the frequency (percent) of respondents covering the subtopics that resulted in a statistically significantly different Chi-square test. There was statistically significant difference in the subtopic coverage between the two study groups in 15 of the 89 subtopics. Those 15 subtopics are listed in Table 5. The largest difference in coverage between the two groups was for Descriptive Chemistry/Periodicity: Organic. The number (%) of professors that covered Descriptive Chemistry/Periodicity: Organic was 76 (56.3%) for the Community College group and 28 (31.5%) for the University group ($p = 0.000$).

Considering the list of ACS Exam subtopics (see Appendix B), the GCTC scores (see Table 4), the comprehensive subtopic comparisons (see Appendix E) along with the information in Table 5, some noticeable trends emerge. As a whole, community college professors cover more content of these 15 subtopics than university professors as evidenced by the GCTC scores. Less than half of the university respondents cover nuclear topics (reactions, equations, decay, stability, etc.) compared to almost two-thirds of community college respondents. This could be due to the fact that universities offer upper level courses of which nuclear chemistry might be discussed at more depth than at the introductory level. The ACS Exam matrix does not include molecular orbital theory. Less than half of all respondents cover metallic bonding. These two items go hand-in-hand since molecular orbital theory is needed to adequately explain metallic bonding. Also, these findings are consistent with Spencer's (1992) views.

Table 5

Chi Square Values for Subtopics Showing Statistically Significant Difference

Topic: Subtopic	Number (percent) covering subtopic		Chi square	<i>p</i>
	Community College*	University*		
Atomic structure: Nuclear reactions/balancing/types	87 (64.4%)	45 (50.6%)	4.271	0.039
Atomic structure: Nuclear stability/decay	85 (63.0%)	38 (42.7%)	8.898	0.003
Dynamics: Rates and stoichiometry	131 (97.0%)	77 (86.5%)	8.950	0.003
Equilibrium: Acid-base theories	132 (97.8%)	81 (91.0%)	5.259	0.022
Equilibrium: Titration curves	121 (89.6%)	69 (77.5%)	6.101	0.014
Equilibrium: pH	133 (98.8%)	78 (87.6%)	11.610	0.001
Equilibrium: Buffers	129 (95.6%)	75 (84.3%)	8.402	0.004
Descriptive chemistry/periodicity: Periodic table notation	129 (95.6%)	75 (84.3%)	8.402	0.004
Descriptive chemistry/periodicity: Inorganic/main group elements	109 (80.7%)	57 (64.0%)	7.792	0.005
Descriptive chemistry/periodicity: Transition elements, coordination chemistry	76 (56.3%)	36 (40.4%)	5.388	0.020
Descriptive chemistry/periodicity: Organic	76 (56.3%)	28 (31.5%)	13.302	0.000
Descriptive chemistry/periodicity: Modern materials	38 (28.1%)	12 (13.5%)	6.653	0.010
States of Matter/Solutions: Kinetic molecular theory	134 (99.3%)	83 (93.3%)	6.380	0.012
States of Matter/Solutions: Classification of matter	129 (95.6%)	78 (87.6%)	4.791	0.029
Experimental: Safety	103 (76.3%)	56 (62.9%)	4.658	0.031

*Community College *n* = 135; University *n* = 89

A lower percentage of university respondents compared to community college respondents covers acid-base theories. Perhaps a more striking result is that significantly more community college respondents include titration curves, pH, and buffers in their general chemistry course than their university counterparts. Since the subtopics were merely listed and not explained, it is difficult to conclude whether this finding is in agreement with Spencer's (1992) proposed curriculum or not. Another explanation may be that university lecture professors might depend on the lab instructor or teaching assistant to cover these subtopics in favor of freeing up lecture time for more depth on other topics. However, since this research did not study the depth of coverage for the subtopics, it is impossible to know for certain whether this is the case. Interestingly, university respondents cover the concept of common ion, but they don't necessarily make the connections in their lectures to buffers although these two subtopics are closely related. With almost 30% of general chemistry students being science majors, this significant omission of titration curves, pH and buffers could be critical to students. "Buffers are of the first importance" (Hawkes, 1992, p. 831). Granted that over 96% of university respondents cover titrations from a stoichiometry standpoint and that a large part of titration curves is based on stoichiometry, titration curves incorporate concepts that extend well beyond stoichiometry. The concepts for titration curves are ones that would serve science majors well as they pursue analytical chemistry and biochemistry courses. Perhaps the university respondents realize their science majors will be taking these upper level courses at their institution and don't feel a need to incorporate the previously mentioned equilibrium subtopics. On the other hand, community college professors must prepare their students not only for

subsequent courses regardless of where the student matriculates but also for no further chemistry courses as in the case of vocational or technical degrees. This puts the onus on community college professors to cover more subtopics. In this regard, there is a parallel between the multiple purposes of community college chemistry courses and high school chemistry courses as pointed out by Deters (2003). Also, “each teacher, no matter at what level of instruction, feels that it is his or her responsibility to prepare students for the next higher level of instruction” as Yager is cited by Mitchell (1989, p. 564).

There is comparable coverage of gases and gaseous behavior between the two groups. This makes the statistically significant difference between the study groups in coverage of Kinetic Molecular Theory of little consequence. As for the statistically significant difference in the coverage of classification of matter, it is the opinion of some that this should be knowledge acquired in high school chemistry (Deters, 2003), and, thus, pales the disparity found in this study.

Both groups cover the experimental topic least, descriptive chemistry/periodicity topic second least and electrochemistry/redox third least as compared to the other topics. The decreased coverage of electrochemistry/redox seems consistent with much published work about the difficulty of this topic as well as the multifaceted issues related to misconceptions in electrochemistry (Garnett & Treagust, 1992; Ogude & Bradley, 1994; and Sanger & Greenbowe, 1999).

The second least covered topic by both study groups, *descriptive chemistry/periodicity*, is consistent with the emphasis shift away from descriptive chemistry topics reported in the literature (Jones & Roswell, 1973; Taft, 1990). The

percentage of community college respondents covering organic concepts in their general chemistry course is almost twice that of university respondents. Albeit low for both groups, community college respondents are two times more likely to cover modern materials than university respondents. Organic and modern materials are classified by Taft (1997) as “every day living” topics. She reported in 1997 that there was a noticeable shift towards these topics. Actually, the idea of including organic chemistry in the first year curriculum is not new. It appears in the literature as early as 1927 (Whitmore, 1927) and continues to be discussed to the present day (Ege, Coppola, & Lawton, 1997; Meade, 2006), as evidenced by the organic emphasis seen in current general chemistry textbooks (Kelter & Mosher, 2007; Moore, Stanitski & Jurs, 2005; Silberberg, 2006).

The *experimental* topic is the least covered topic by both groups. This could largely be due to the laboratory component being a separate entity from the lecture. The lecture instructor could be depending on the laboratory instructor to cover experimental concepts with the students and choosing to leave these subtopics out in order to spend more time on the other necessary topics. However, it is important to note that safety is discussed more often in community college than in university general chemistry lectures. As important as safety is, it might be worthwhile for all general chemistry professors to reinforce safety by including it in their lectures.

Research Question 2

Research question 2 of this study is: Considering both community colleges and universities, is there a difference in mean GCTC score between the different designated

U.S. regions?

Tables 6 and 7 show the community college and university mean GCTC scores for each U.S. region, analysis of variance (ANOVA) comparison of mean GCTC scores for the five U.S. regions, and Tukey's honestly significant difference (HSD) test for mean differences in GCTC scores between the U.S. regions. The mean GCTC score (*SD*) for the regions were: Western 78.13 (9.74), Central 77.98 (8.84), Eastern 69.87 (12.43), Southern 74.09 (9.62), and Southwestern 78.06 (7.00).

Table 6

Data and ANOVA Table for U.S. Region with GCTC Score

Region	GCTC score	
	<i>n</i>	Mean (<i>SD</i>)
Western	32	78.13 (9.74)
Central	61	77.98 (8.84)
Eastern	39	69.87 (12.43)
Southern	45	74.09 (9.62)
Southwestern	47	78.06 (7.00)
Total	224	75.82 (9.94)

ANOVA Table

Source	<i>SS</i>	<i>df</i>	<i>MS</i>	<i>F</i>	<i>Sig.</i>
Between groups	2206.914	4	551.729	6.093	0.000
Within groups	19829.296	219	90.545		
Total	22036.210	223			

Table 7

Tukey's HSD Test for Differences in Mean GCTC Score Between U.S. Regions

Region	Mean GCTC score	Western	Central	Eastern	Southern	Southwestern
		78.12	77.98	68.87	74.09	78.06
Western	78.12		1.000	0.003*	0.357	1.000
Central	77.98	1.000		0.000*	0.231	1.000
Eastern	68.87	0.003*	0.000*		0.257	0.001*
Southern	74.09	0.357	0.231	0.257		0.268
Southwestern	78.06	1.000	1.000	0.001*	0.268	

* = $p < 0.05$

There is a statistically significant difference in mean GCTC scores between the Eastern and Western, Eastern and Central, and Eastern and Southwestern U.S. regions. All other U.S. region mean GCTC scores were not statistically significantly different. The Eastern region is made up of the most states, 13, followed by the Central region with 12 states, Western with 11 states, then Southern and Southwestern, each with 7 states. However, there is no similarity seen between the number of states in a region and whether its mean GCTC score was statistically significantly different from the other regions. Table 8 lists the number and percent of responses for each region by institution type. There is no connection found between the percentage of community college and university responses in a region with its mean GCTC score.

Table 8

Number of Responses (Percent of Region Total) by Type of Institution per U.S. Region

Region	Number of responses (Percent of region total)		
	Community college	University	Total (% of 224)
Western	25 (78%)	7 (22%)	32 (14%)
Central	32 (54%)	27 (46%)	59 (26%)
Eastern	22 (55%)	18 (45%)	40 (18%)
Southern	29 (64%)	16 (36%)	45 (21%)
Southwestern	27 (56%)	21 (44%)	48 (20%)

Research Question 3

Research question 3 of this study is: Considering both community college and university professors, is there a difference in GCTC score for professors with a master's degree compared to those with a doctorate?

Figure 3 is an error bar chart which shows the average (and 95% confidence interval for the average) GCTC score, separately for respondents with a Master's Degree versus respondents with a Doctorate. The graph shows almost no difference in the average GCTC score between the two groups. Table 9 shows that there was not a statistically significant difference in the average GCTC scores between the two groups. The average GCTC score (*SD*) was 76.2 (10.1) versus 75.7 (9.9) for the Master's and Doctorate groups, respectively ($t = 0.33$; $df = 222$; $p = 0.75$).

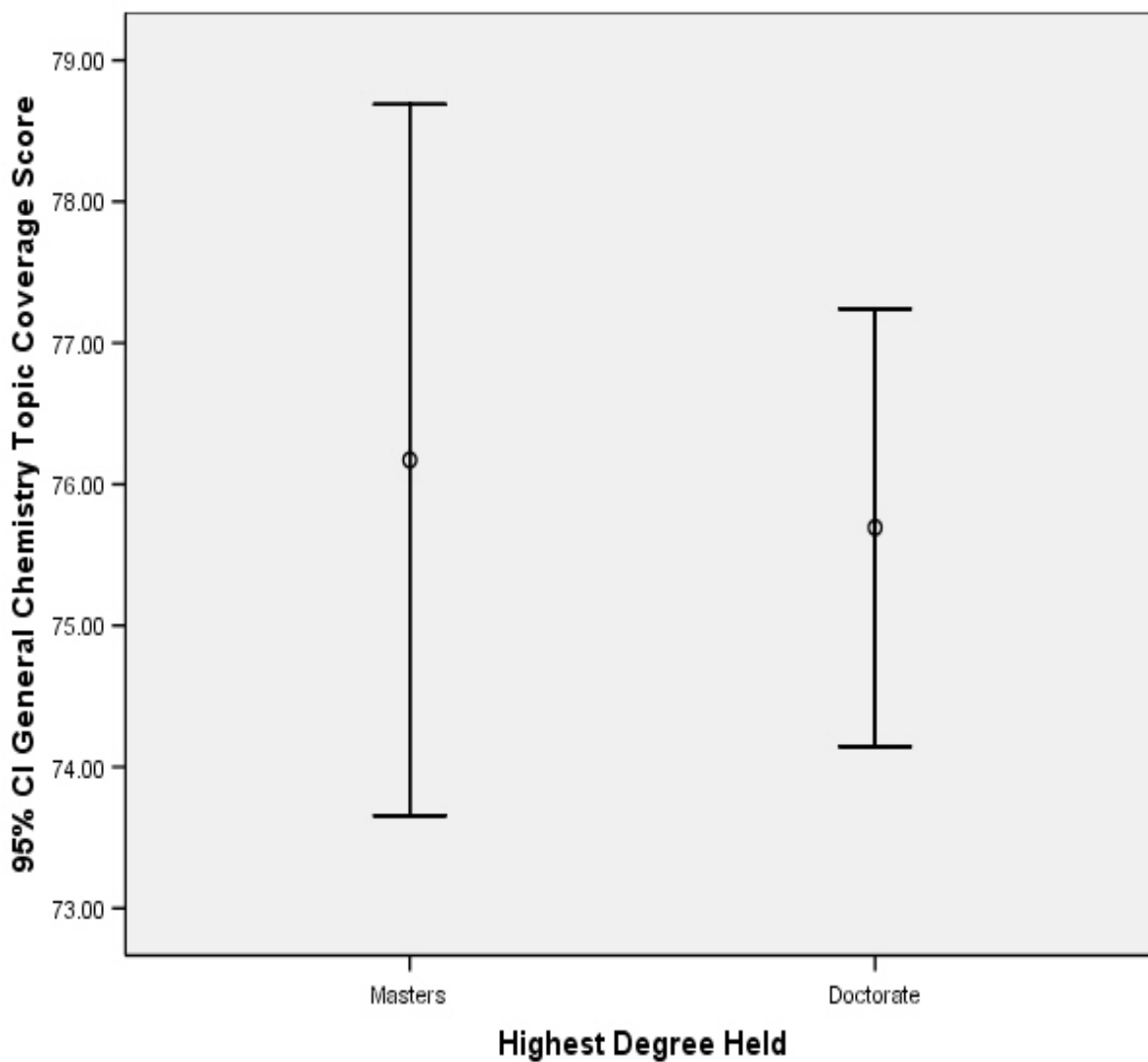


Figure 3. Error bar chart for highest graduate degree held by faculty depicting the range of GCTC scores, with $\bar{X} = 76.17$ (10.07) for master's-degreed faculty and $\bar{X} = 75.69$ (9.92) for doctorate-degreed faculty.

Table 9

GCTC Score Comparison per Highest Degree Held

		GCTC Score	
		<i>n</i>	Mean (<i>SD</i>)
Highest degree held	Master's	64	76.17 (10.07)
	Doctorate	160	75.69 (9.92)

There are a couple of factors that are possibly affecting the results. First, the obtained result of GCTC score for community college versus university respondents would lead one to expect that there would be a similar difference in GCTC score and degree held. Collected data have few, 3 (3.4%), university respondents holding a Master's degree, which is typical and consistent with other researcher's findings (Zimbler, 2001). The high percentage of community college respondents holding a Doctorate degree is about 2.5 times larger than Zimbler's (2001) reported findings of 20%, but it is almost exactly the same as Ryan, Neuschatz, Wesemann, and Boese's (2003) reported findings of 54%. To put the above results in perspective, one must remember that $n = 224$ for this study's total sample, $n = 135$ for community college respondents, and $n = 89$ for university respondents. The sample size in this study is ample as compared to $n = 105$ in Nechamkin's (1961) study, $n = 194$ in Jones and Roswell's (1973) study, $n = 114$ in Taft's (1990) study, $n = 166$ in Taft's (1997) study, and $n = 100$ in Mitchell's (1993) study. Additionally, the sample represented responses from 46 states with fairly even geographic distribution as previously presented in Chapter 3.

The median GCTC scores for professors holding a Master's and those with a Doctorate are the same with mean scores that are not statistically significantly different. Despite what one might expect in terms of course content for a professor with a Doctorate versus one with a Master's, there is no significant difference between the two.

Research Question 4

Research question 4 of this study is: Is there a correlation between GCTC score and percentage of students that major in science?

Figure 4 is a scatter plot that shows the relationship between GCTC score and percentage of professor's students majoring in science. The graph shows no evidence of a trend. This could be due to the fact that the data collected was categorical. Table 10 shows that there was not a statistically significant correlation between GCTC score and percentage of professor's students majoring in science, $\rho = -0.039$, $p = 0.57$.

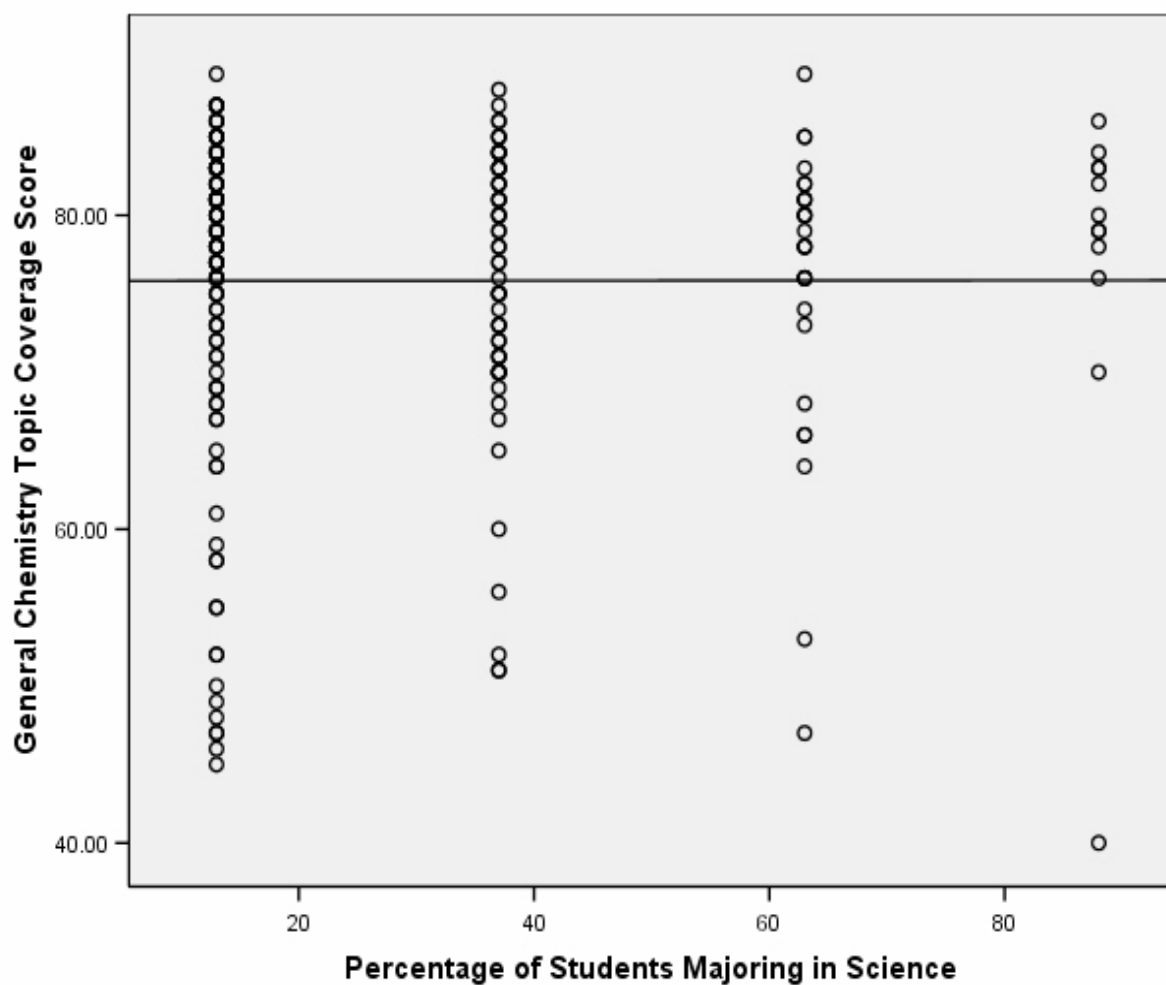


Figure 4. GCTC score plot as a function of percentage of study participants' students majoring in science.

Table 10

Correlation Coefficient for GCTC Score and Percentage of Students Majoring in Science

		Percentage of respondent's students majoring in science
Spearman's rho	Correlation Coefficient	-0.039
	p	0.566
	n	224

Bunce and Hutchinson (1993) found that science majors demonstrated higher scores on the Group Assessment of Logical Thinking (GALT) test as well as on the Math and Verbal Scholastic Aptitude Test (SAT) than nonscience and nursing majors. The general chemistry course serves not only science majors but also students of diverse academic majors, interests and abilities. Thus, it makes sense that course content was not found to show correlation with student major.

Summary

This study, with $n = 224$, showed that there is a statistically significant difference in general chemistry course content between U.S. community colleges and universities. There was statistically significant difference in general chemistry course content between the Eastern U.S. region and the Western, Central, and Southwestern regions.

There was no statistically significant difference in general chemistry course content between master's-degreed and doctorate-degreed professors found. There was no statistically significant correlation between general chemistry course content and percentage of students who are science majors. Moreover, the areas where general chemistry course content differed between community colleges and universities were identified.

CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter summarizes and draws conclusions from the results of the quantitative cross-sectional design study conducted with general chemistry instructors at U.S. community colleges and universities. The investigation evaluated five research questions. Also included in this chapter are suggestions for future research.

Summary

General chemistry is a foundation course that is taken by a large number of students in the U.S.. Nearly half of the students taking the course do so at a community college. There have been several studies that investigated general chemistry course content; however, they were limited in that they targeted a specific population, focused at the state level rather than nationally, or didn't include community colleges in the study. The two studies reported in the literature that included community colleges were done well over three decades ago.

The objective of this investigation was to determine whether there is a difference between general chemistry course content taught at U.S. community colleges and universities. This objective was accomplished by surveying 224 chemical educators (135 from community colleges and 89 from universities) from U.S. community colleges and universities who teach the general chemistry course and comparing the mean General Chemistry Content Coverage (GCTC) scores that I created for this study as a

measure of content coverage for each of the two study groups. The comparisons were done by statistical analysis of the group mean GCTC scores. The GCTC score was based on the number of ACS 2003 General Chemistry Exam subtopics each self-reporting respondent indicated they include in their course. The mean GCTC score was used to answer the following research questions:

1. Is there a difference in mean GCTC scores between U.S. community colleges and four-year colleges and universities?
 - 1.1. If there is a difference in mean GCTC score between the two study groups, what are the observed differences in subtopics covered between community colleges and universities?
2. Considering both community colleges and universities, is there a difference in the mean GCTC score between the different designated U.S. regions?
3. Considering both community college and university professors, is there a difference in GCTC score for professors with a master's degree compared to those with a doctorate?
4. Is there a correlation between GCTC score and percentage of students that major in science?

Both descriptive and inferential statistical analyses of the data were used.

Outputs of sample means, standard deviations, degrees of freedom, and the resultant t - and Chi-square distributions two-tailed t -tests were the basis for determining the significance of the course content relationship as it pertains to type of institution and the earned degree of the professor teaching the course between the sample groups being compared. Also, the output of the correlation coefficient and the resultant p -value were

the basis for determining the relationship between course content and percentage of students majoring in science.

The p -values, at an alpha level of 0.05, indicate that there is statistically significant difference between course content at community colleges and universities. This finding seems to parallel Russell and Perez's statement, in discussing the University of California system, "the level of instruction in the physical sciences in community colleges, state colleges, and universities differs" (1980, p. 67). Also indicated by the analysis of this research study, there is no statistically significant difference in course content of general chemistry courses taught by professors with an earned master's and professors with an earned doctorate degree. Additionally, the p -value at an alpha level of 0.05, the results of the correlation coefficient analysis indicate no correlation between course content and percentage of students majoring in science.

Conclusions

The conclusions to be drawn from the results of this research for each research question follow.

1. Is there a difference in mean GCTC scores between U.S. community colleges and four-year colleges and universities?

Yes. The mean GCTC score for community colleges was higher than that for universities. Therefore, one can make the statistical inference that community college general chemistry course content is different from university general chemistry course content. One might argue that professors with an earned doctorate have more academic depth. It is expected, then, that those with a doctorate possibly spend more

time in class going into more depth on certain topics leaving less time to cover more content compared to their counterparts with only an earned master's. With more doctorate-degreed faculty at universities than at community colleges, this argument supports the research findings; however, I cannot draw conclusions without further research.

- 1.1 If there is a difference in mean GCTC score between the two study groups, what are the observed differences in subtopics covered between community colleges and universities?

There is statistically significant difference in 15 of the 89 subtopics (16.9% of general chemistry course content) in terms of the percentage of professors from community colleges and universities who cover those subtopics. The differences were in the subtopics of nuclear reactions, balancing, types; nuclear stability and decay; rates and stoichiometry; acid-base theory; titration curves; pH; buffers; periodic table notation; inorganic descriptive chemistry and main group elements; transition elements and coordination chemistry; organic; modern materials; kinetic molecular theory; classification of matter; and safety. Two of the 15 subtopics were under the topic of atomic structure; one was under the topic of dynamics; four were in the topic of equilibrium; five were in the topic of descriptive chemistry and periodicity; two were in the topic of states of matter and solutions; and one was in the topic of experimental. Additionally, findings of descriptive chemistry being the second least covered topic are consistent with those reported by Taft (1990). Although there has been a 16-year span between Taft's findings and this study, the same trend of decreased emphasis on descriptive chemistry topics holds true today. As in Nechamkin (1961), Jones and

Roswell (1973), and Taft's (1990) studies, we see that theoretical topics, such as chemical bonding, equilibrium concepts, atomic and quantum theory, and energy concepts, are still being stressed today. This conclusion is of importance especially to textbook publishers and authors who might be interested in long-term instructional tendencies.

2. Considering both community colleges and universities, is there a difference in the mean GCTC score between the different designated U.S. regions?

Yes. The mean GCTC score for the Eastern U.S. region was found to be statistically significantly different from those of the Western, Central, and Southwestern regions. However, the mean GCTC score for the Eastern U.S. region was not statistically significantly different from that of the Southern region. Moreover, the Western, Central, and Southwestern were not statistically significantly different from each other.

3. Considering both community college and university professors, is there a difference in GCTC score for professors with a master's degree compared to those with a doctorate?

No. The mean GCTC score for professors with a master's degree was the same as that for professors with a doctorate degree. Therefore, one can make the statistical inference that professors with a master's degree cover the same material as professors with a doctorate. From a practical view, it is important to note that there was a relatively high percentage of community college respondents in this study who had an earned doctorate, the percentage of which was about 2.5 times greater than that previously

reported (Zimbler, 2001). However, the percentage of community college professors holding a doctorate (54.8%) is in agreement with Ryan, Neuschatz, Wesemann, and Boese's (2003) findings (54%). The findings associated with this research question indicate that at community colleges, on average, chemistry faculty have earned higher degrees than the faculty as a whole. Consequently, national community college studies that consider faculty in all disciplines may not be fully applicable to chemistry faculty specifically.

4. Is there a correlation between GCTC score and percentage of students that major in science?

No. The mean GCTC score showed no correlation with the percentage of the professor's students majoring in science. Therefore, one can make the statistical inference that percentage of science majors in a class does not influence or affect course content. This finding could be due to the fact that the respondents' institutions do not have separate general chemistry tracks according to major. Hence, the students enrolled in the respondents' courses are majoring in a wide variety of fields of study. It might also be a result of the data having been categorical.

Recommendations for Future Study

On the basis of the data presented in this study and the results obtained, recommendations for future research are in order. Furthermore, some participants in this study provided comments on what questions they would like to see answered, which I pose here as ideas for other researchers.

Having found that there is a statistically significant difference between general chemistry course content at community colleges and universities, one might be interested to determine: Is there a difference in course content between different types of community colleges? Is there a difference in course content between different types of universities?

Repetition of this study with some changes to the survey instrument would be interesting. Especially, other researchers need to employ the newly developed GCTC in order to check and establish its reliability and validity. Also, the subtopic data collected in this study were adequate; however, the survey would provide more information if it is designed where the respondent is asked to indicate on a Likert scale the importance of each subtopic, like in Nechamkin's (1961) and Jones and Roswell's (1973) studies, rather than simply whether they do or don't cover the subtopic. Doing so could possibly provide insight as to the depth of coverage for the subtopics. To do research that would compare to previously published work, one could include survey items that ask about course prerequisite requirements, placement test, and success rate of students completing the course with grade of A, B, or C.

The statistically significantly different results found for the mean GCTC score per U.S. region was unexplainable. It would be enlightening to have this research question explored further. There is a greater concentration of private institutions in the Eastern U.S. region. Might there be a relation between public vs. private institution and GCTC score, or is there another relation that explains this finding?

For future research aimed at revealing possible correlation between course content and the percentage of students in various majors, it is advisable to gather data

on a continuous scale rather than categorical scale. The data collected would be more meaningful. Although this study revealed no correlation between general chemistry course content and percentage of students majoring in science, this result could be due to the fact that the respondents sampled were not selected according to whether they have general chemistry courses for specific tracks (e.g., course designed for engineering students). If another investigator chose to survey those who have different tracks of general chemistry according to I expect that there might well be a correlation between course content and student majors. Moreover, this study revealed a difference between community college and university in percentage of respondent's students majoring in science. Perhaps, when continuous data are collected determining mean percentage of general chemistry students majoring in science, a multivariate analysis of course content, percentage of students majoring in science and type of institution might be prudent. This study also revealed, and perhaps expectedly so, a huge difference in the average class size between the two types of institutions. Consequently, further research could explore differences in course content based on class size.

The following questions would also be interesting to study: Is descriptive chemistry taught separately, or is it integrated with other topics? What emphasis is given to theoretical chemistry and what emphasis is given to descriptive chemistry? In what order are the topics covered? Is there a difference in depth of topic and/or subtopic coverage between various groups? Those who are interested in provocative questions could investigate: Are topics like nuclear chemistry, coordination chemistry, and organic chemistry essential, even desirable, in general chemistry curriculum? There are some (Gillespie, 1992; Spencer, 1992, 2006) who think not. The question could be studied in

terms of specific student majors. Other investigators might be interested in using the data collected in this dissertation research to pursue a mixed design study where both quantitative and qualitative methods are used. For example, they could interview practitioners, students, and faculty to gather the opinion of those groups about course content as it pertains to a particular field and combine both qualitative and quantitative aspects in answering the question of desirable content.

The data collected in this study included two respondents who were from outside the U.S. This raises the question: How does U.S. and non-U.S. general chemistry course content compare?

One of the limitations of this study is that professors were classified as either having a master's or a doctorate. There was no distinction made between the different disciplines of the master's or doctorate. Accordingly, future research could aim to determine whether there is a difference in general chemistry course content between professors with a degree in chemistry, those with a science education or chemistry education degree, and those with a degree in another field.

Lastly, it has been important to determine and establish course content comparison, but research of the effect of course content on student performance and outcomes remains to be studied. A suggested way to conduct such a study is to gather the item analysis for a standardized ACS General Chemistry Exam and survey the same institutions that participated in the standardization of the ACS exam to determine course content. In my way of thinking, acquiring knowledge and thinking skills as measured by student outcomes and success is what teaching is about in the first place.

APPENDIX A
ONLINE SURVEY INSTRUMENT

Demographics and Access to Survey

Please answer the following questions and when ready, click on SUBMIT to start. **The survey itself is intended to address the complete first year of general chemistry (not just one semester or quarter).** The survey takes 15-20 minutes to complete. Most questions have pre-selected answers. Once you have completed the survey, you will have the opportunity to make any additional personal comments you wish.

If you have any problems with this form, please contact my programmer [here](mailto:bherrick@mines.edu) (bherrick@mines.edu).

Thanks!

Personal Information

First Name:

Last Name:

Highest degree held:

Select one:

PhD (Chemistry)

PhD (Chemistry Education)

PhD (Science Education)

Master's (Chemistry)

Master's (Chemistry Education)

Master's (Science Education)

Master's (Other)

Bachelor's (Chemistry)

Bachelor's (Chemistry Education)

Bachelor's (Other)

Academic title:

Select one:

Professor of Chemistry Associate Professor

Assistant Professor

Instructor/Lecturer

E-mail address:

School Information

Name of School:

City:

State/Country:

Type of School:

Select one:

two-year

four-year (<5000 students)

four-year (<15000 students)

four-year (<25000 students)

four-year (>25000 students)

Terms:

Select one:

Quarters

Semesters

Lecture Format:

Select one:

One hour, three times a week

75/80 minutes, two times a week

Three hours, once a week

Other (please specify)

Other:

Courses Taught this semester:

Select one:

General Chemistry I

General Chemistry II

Both courses

Other

Textbook used:

Brown et al.

McMurry-Fay

Ebbing

Zumdahl

Whitten et al.

Hill-Petrucci

Silberberg

Chang

Umland

Robinson

Bodner

Birk

Other (please specify)

Average class size:

Up to 30

30-60

60-100

100-200

200-300

300+

Please indicate the percentage of your students majoring in:

Pre-professional (medical, dental, etc.)

0-25%

26-50%

51-75%

76-100%

Science

0-25%
26-50%
51-75%
76-100%

Engineering

0-25%
26-50%
51-75%
76-100%

Other

0-25%
26-50%
51-75%
76-100%

Please specify:

Average age of students in your class:

18-22
23-28
28-32
33+

University Admission/Entrance requirements:

SAT entrance score:

ACT entrance score:

None

Does your state require "high stakes" exams for students to complete their high school diploma?

Yes

No

If yes, what effect have you observed on student achievement in your class?

Very positive

Positive

None

Negative

Very negative

Number of Full-time/Part-time instructors for General Chemistry Courses:

Full-time female:

None

1-2

3-4

5-7

8-10

11-15

16+

Full-time male:

None

1-2

3-4

5-7

8-10

11-15

16+

Part-time female:

None

1-2

3-4

5-7

8-10

11-15

16+

Part-time male:

None

1-2

3-4

5-7

8-10

11-15

16+

How is your general chemistry program designed?

Separate lecture and lab courses

Separate lecture, lab and recitation courses

Lecture, lab and recitation as one course

Lecture and lab as one course

Please estimate the percentage of students that drop or withdraw from your course:

Less than 10%

10-20%

20-30%

30-40%

40-50%

More than 50%

Please estimate the percentage of students that go on to take organic chemistry

Less than 25%

25-50%

51-75%

More than 75%

SUBMIT

RESET

Welcome and thank you for taking my survey! Below are 10 topics for your comments. Please choose one answer for each subtopic. You may only submit once and then only after all subtopics have an entry. At the end of the survey you will have the opportunity to make any comments.

1. On the subject of ATOMIC STRUCTURE, I lecture:

< 1 period 1 period 2 periods 3 periods 4 periods > 4 periods

Please indicate what subtopics below are included in your lecture:

Cover

Don't Cover

1. Experimental basis
2. Atomic symbols/isotopes
3. Atomic mass
4. Atomic spectra/Bohr theory
5. Quantum theory
6. Electron configurations
7. Nuclear reactions/balancing/types
8. Orbital shapes (not hybrids) and energies
9. Electron configurations
10. Nuclear reactions/balancing/types
11. Nuclear stability/decay

2. On the subject of MOLECULAR STRUCTURE, I lecture:

< 1 period 1 period 2 periods 3 periods 4 periods > 4 periods

Please indicate what subtopics below are included in your lecture:

Cover

Don't Cover

1. Nomenclature
2. Lewis structures
3. Molecular geometry/VSEPR
4. Ionic bonding/crystal structures
5. Covalent bonding/hybrid orbitals
6. Electronegativity/ polarity of bonds and molecules
7. Bond order/bond strength
8. Metallic bonding

3. On the subject of DYNAMICS, I lecture:

< 1 period 1 period 2 periods 3 periods 4 periods > 4 periods

Please indicate what subtopics below are included in your lecture:

Cover

Don't Cover

1. Rates and stoichiometry
2. Determination of reaction order
3. Rate laws
4. Half-lives
5. Collision theory
6. Temperature dependence/Arrhenius equation
7. Energy diagrams: Catalysis
8. Mechanisms
9. Diffusion/effusion

4. On the subject of EQUILIBRIUM, I lecture:

< 1 period 1 period 2 periods 3 periods 4 periods > 4 periods

Please indicate what subtopics below are included in your lecture:

Cover

Don't Cover

1. Gaseous/Heterogeneous
2. Le Châtelier's Principle/K vs. Q
3. Precipitation/ K_{sp}
4. Acid-Base Theories
5. Common ion effect
6. Titration curves
7. K_a , K_b , K_w /Salt hydrolysis
8. pH
9. Buffers

5. On the subject of STOICHIOMETRY, I lecture:

< 1 period 1 period 2 periods 3 periods 4 periods > 4 periods

Please indicate what subtopics below are included in your lecture:

Cover

Don't Cover

1. Mole concept
2. Mass/mole/formula unit
3. Empirical/molecular formula
4. Balancing equations (not redox)
5. Net ionic equations
6. Limiting reagent/excess reagent
7. Theoretical yield/percent yield
8. Solution stoichiometry and titration
9. Stoichiometry and enthalpy
10. Stoichiometry and gases

6. On the subject of ENERGETICS, I lecture:

< 1 period 1 period 2 periods 3 periods 4 periods > 4 periods

Please indicate what subtopics below are included in your lecture:

Cover

Don't Cover

1. Heat capacity
2. Calorimetry
3. Heat/work/energy
4. Enthalpy/standard states
5. Hess' Law
6. Heat of formation
7. Phase changes/energy
8. Entropy
9. Free energy/equilibrium

7. On the subject of ELECTROCHEMISTRY/REDOX, I lecture:

< 1 period 1 period 2 periods 3 periods 4 periods > 4 periods

Please indicate what subtopics below are included in your lecture:

Cover

Don't Cover

1. Oxidation numbers
2. Oxidizing/reducing agents
3. Balancing redox reactions
4. Galvanic cells: Theory
5. Use/interpretation of E° tables/activity series
6. Nernst equation
7. ΔG , E° K relationships
8. Electrolytic cells/Faraday's Law
9. Electrochemical applications: Batteries, corrosion, plating

8. On the subject of DESCRIPTIVE CHEMISTRY/PERIODICITY, I lecture:

< 1 period 1 period 2 periods 3 periods 4 periods > 4 periods

Please indicate what subtopics below are included in your lecture:

Cover

Don't Cover

1. Periodic trends
2. Acidity, reactivity, metallicity
3. Periodic table notation
4. Inorganic/main group elements
5. Transition elements, coordination chemistry
6. Organic
7. Modern materials
8. Prediction of reaction products

9. On the subject of STATES OF MATTER/SOLUTIONS, I lecture:

< 1 period 1 period 2 periods 3 periods 4 periods > 4 periods

Please indicate what subtopics below are included in your lecture:

Cover

Don't Cover

1. Gases: general properties
2. Gas laws
3. Kinetic molecular theory
4. Liquids: general properties
5. Intermolecular forces
6. Concentration units
7. Colligative properties
8. Solubility principles/rules
9. Solids/crystal structures
10. Phase diagrams
11. Classification of matter

10. On the subject of EXPERIMENTAL, I lecture:

< 1 period 1 period 2 periods 3 periods 4 periods > 4 periods

Please indicate what subtopics below are included in your lecture:

Cover

Don't Cover

1. Use of equipment/ instrumentation
2. Precision and accuracy
3. Preparation and analysis of solutions
4. Experimental design
5. Safety
6. Interpreting data/graphs
7. Scientific method/ethics

APPENDIX B

LIST OF ACS 2003 GENERAL CHEMISTRY EXAM TOPICS AND SUBTOPICS

Topic I: Atomic Structure

Experimental basis
Atomic symbols/isotopes
Atomic mass
Atomic spectra/Bohr theory
Quantum theory
Electron configurations
Nuclear reactions/balancing/types
Orbital shapes (not hybrids) and energies
Electron configurations
Nuclear reactions/balancing/types
Nuclear stability/decay

TOPIC II: Molecular Structure

Nomenclature
Lewis structures
Molecular geometry/VSEPR
Ionic bonding/crystal structures
Covalent bonding/hybrid orbitals
Electronegativity/ polarity of bonds and molecules
Bond order/bond strength
Metallic bonding

TOPIC III: Dynamics

Rates and stoichiometry
Determination of reaction order
Rate laws
Half-lives
Collision theory
Temperature dependence/Arrhenius equation
Energy diagrams: Catalysis
Mechanisms
Diffusion/effusion

TOPIC IV: Equilibrium

Gaseous/Heterogeneous
LeChâtelier's Principle/K vs Q
Precipitation/ K_{sp}
Acid-Base Theories
Common ion effect
Titration curves
 K_a , K_b , K_w /Salt hydrolysis
pH
Buffers

TOPIC V: Stoichiometry

Mole concept
Mass/mole/formula unit
Empirical/molecular formula
Balancing equations (not redox)
Net ionic equations
Limiting reagent/excess reagent
Theoretical yield/percent yield
Solution stoichiometry and titration
Stoichiometry and enthalpy
Stoichiometry and gases

TOPIC VI: Energetics

Heat capacity
Calorimetry
Heat/work/energy
Enthalpy/standard states
Hess' Law
Heat of formation
Phase changes/energy
Entropy
Free energy/equilibrium

TOPIC VII: Electrochemistry/Redox

Oxidation numbers
Oxidizing/reducing agents
Balancing redox reactions
Galvanic cells: Theory
Use/interpretation of E° tables/activity series
Nernst equation
 ΔG , E° K relationships
Electrolytic cells/Faraday's Law
Electrochemical applications: Batteries, corrosion, plating

TOPIC VIII: Descriptive Chemistry/Periodicity

Periodic trends
Acidity, reactivity, metallicity
Periodic table notation
Inorganic/main group elements
Transition elements, coordination chemistry
Organic
Modern materials
Prediction of reaction products

TOPIC IX: States of Matter/Solutions

Gases: general properties

Gas laws

Kinetic molecular theory

Liquids: general properties

Intermolecular forces

Concentration units

Colligative properties

Solubility principles/rules

Solids/crystal structures

Phase diagrams

Classification of matter

TOPIC X: Experimental

Use of equipment/instrumentation

Precision and accuracy

Preparation and analysis of solutions

Experimental design

Safety

Interpreting data/graphs

Scientific method/ethics

APPENDIX C

IRB-APPROVED LETTER OF INVITATION FOR THE STUDY

August 8, 2005

Dear Colleague:

I am Amina El-Ashmawy, Professor of Chemistry at Collin County Community College in Plano, Texas, where I have been for over 16 years. I am also completing requirements for a doctoral degree in chemistry education at the University of North Texas. My dissertation will be dealing with a comparative study of general chemistry at community colleges and baccalaureate granting universities. The study's purpose is to gain insight on the possible differences in general chemistry courses taught at community colleges and baccalaureate granting universities. This is important information given that general chemistry is a gateway core course for pre-professional, science and engineering majors and with about half of all chemistry students in the U.S. being enrolled at community colleges.

As a faculty member teaching general chemistry, you represent a critically important source of information related to this study. I am, therefore, soliciting your assistance in completing the survey, which should take about 15 minutes to complete. Knowing the many professional demands on your time, I would be extremely grateful for your voluntary participation in this research project. Rest assured that any information you provide will remain completely confidential. The Internet will be used for administering the survey. The identifying information you provide will aid in knowing the demographics and geographic participation in the survey and will not be disclosed otherwise. Because all responses will be held in strictest confidence, you will incur no foreseeable risk as a participant. The survey results will be directly, electronically entered into a database that compiles the information you provide.

There is certainly no penalty or direct loss of benefit should you choose not to participate. However, I sincerely hope that you will complete the survey on or before October 1, 2005. The survey can be accessed at <http://uts.cc.utexas.edu/~bradchem/amina/>. Your completion of the survey will represent evidence of your voluntary consent to participate in this study. In addition, all participants will receive a summary of their survey responses after submitting the survey.

If you have a colleague who is more suited to fill out this survey, I'd be most appreciative if you would forward this on to them. Any inquiries about this request may be addressed to me at 1889 Hill Crest Dr., Lewisville, TX 75077 or e-mailed to me at ael-ashmawy@ccccd.edu. I can be reached by telephone at either 972.881.5961 or 972.317.3750. You may also contact Dr. Diana Mason, Chair of Dissertation Committee and faculty member in the Department of Chemistry at the University of North Texas at dmason@unt.edu.

This research study has been reviewed and approved by the UNT Institutional Review Board (IRB). Contact the IRB at 940.565.3940 or sbourns@unt.edu if there are any questions regarding your rights as a research subject.

As a colleague in the great work of chemistry education, I want you to know in advance how much I appreciate your time and your assistance. Many, many thanks!

Sincerely,



Amina K. El-Ashmawy
Graduate Student and Doctoral Candidate
Department of Chemistry
The University of North Texas

APPROVED BY THE UNT IRB
FROM 5/9/05 TO 5/2/06

1 of 1

APPENDIX D
STATES IN EACH U.S. REGION

Table A1

	U.S. Region				
	Western	Central	Eastern	Southern	Southwestern
States	Washington	North Dakota	Maine	North Carolina	Colorado
	Oregon	South Dakota	New Hampshire	South Carolina	New Mexico
	California	Nebraska	Vermont	Georgia	Kansas
	Nevada	Minnesota	Maine	Florida	Oklahoma
	Arizona	Iowa	Rhode Island	Tennessee	Texas
	Utah	Missouri	Connecticut	Mississippi	Arkansas
	Idaho	Wisconsin	New York	Alabama	Louisiana
	Montana	Michigan	New Jersey		
	Wyoming	Illinois	Delaware		
	Hawaii	Indiana	Pennsylvania		
	Alaska	Ohio	West Virginia		
		Kentucky	Virginia		
			Maryland		

APPENDIX E

PEARSON CHI SQUARE VALUES FOR SUBTOPICS

Table A2

Pearson Chi Square Values for Atomic Structure Subtopics

Subtopic	Number of respondents (%) covering subtopic		Pearson Chi square value	<i>p</i>
	Community college*	University*		
Experimental basis	111 (82.2%)	73 (82.0%)	0.001	0.970
Atomic symbols/Isotopes	134 (99.3%)	88 (98.9%)	0.089	0.766
Atomic mass	134 (99.3%)	87 (97.8%)	0.921	0.337
Atomic spectra/Bohr model	120 (88.9%)	80 (89.9%)	0.056	0.813
Quantum theory	120 (88.9%)	80 (89.9%)	0.056	0.813
Orbital shapes (not Hybrids) and energies	128 (94.8%)	85 (95.5%)	0.055	0.815
Electron configuration	134 (99.3%)	87 (97.8%)	0.921	0.337
Nuclear Reactions/Balancing/Types	87 (64.4%)	45 (50.6%)	4.271	0.039
Nuclear stability/Decay	85 (63.0%)	38 (42.7%)	8.898	0.003

*Community college *n* = 135; University *n* = 89

Table A3

Pearson Chi Square Values for Molecular Structure Subtopics

Subtopic	Number of respondents (%) covering subtopic		Pearson Chi square value	<i>p</i>
	Community college*	University*		
Nomenclature	128 (94.8%)	80 (89.9%)	1.963	0.161
Lewis structure	135 (100.0%)	87 (97.8%)	3.061	0.080
Molecular geometry/VSEPR	130 (96.3%)	87 (97.8%)	0.376	0.540
Bonding/Crystal structures	116 (85.9%)	77 (86.5%)	0.016	0.900
Covalent bonding/Hybrid orbitals	131 (97.0%)	84 (94.4%)	0.980	0.322
Electronegativity/Polarity of bonds and molecules	134 (99.3%)	87 (97.8%)	0.921	0.337
Bond order/Bond strength	110 (81.5%)	80 (89.9%)	2.944	0.086
Metallic bonding	67 (49.6%)	41 (46.1%)	0.273	0.602

*Community college *n* = 135; University *n* = 89

Table A4

Pearson Chi Square Values for Dynamics Subtopics

Subtopic	Number of respondents (%) covering subtopic		Pearson Chi square value	<i>p</i>
	Community college*	University*		
Rates and stoichiometry	131 (97.0%)	77 (86.5%)	8.95	0.003
Determination of reaction order	125 (92.6%)	77 (86.5%)	2.236	0.135
Rate laws	125 (92.6%)	77 (86.5%)	2.236	0.135
Half-lives	120 (88.9%)	73 (82.0%)	2.121	0.145
Collision theory	121 (89.6%)	72 (80.9%)	3.429	0.064
Temperature dependence/Arrhenius equation	117 (86.7%)	72 (80.9%)	1.354	0.245
Energy diagrams: Catalysis	120 (88.9%)	74 (83.1%)	1.525	0.217
Mechanisms	104 (77.0%)	67 (75.3%)	0.092	0.762
Diffusion/Effusion	89 (65.9%)	49 (55.1%)	2.679	0.102

*Community college *n* = 135; University *n* = 89

Table A5

Pearson Chi Square Values for Equilibrium Subtopics

Subtopic	Number of respondents (%) covering subtopic		Pearson Chi square value	<i>p</i>
	Community college*	University*		
Gaseous/Heterogeneous	122 (90.4%)	76 (85.4%)	1.295	0.255
Le Châtelier's principle/K vs Q	130 (96.3%)	81 (91.0%)	2.741	0.098
Precipitation/ K_{sp}	117 (86.7%)	75 (84.3%)	0.252	0.616
Acid base theories	132 (97.8%)	81 (91.0%)	5.259	0.022
Common ion effect	118 (87.4%)	75 (84.3%)	0.443	0.506
Titration curves	121 (89.6%)	69 (77.5%)	6.101	0.014
K_a , K_b , K_w /Salt hydrolysis	126 (93.3%)	78 (87.6%)	2.138	0.144
pH	133 (98.5%)	78 (87.6%)	11.610	0.001
Buffers	129 (95.6%)	75 (84.3%)	8.402	0.004

*Community college $n = 135$; University $n = 89$

Table A6

Pearson Chi Square Values for Stoichiometry Subtopics

Subtopic	Number of respondents (%) covering subtopic		Pearson Chi square value	p
	Community college*	University*		
Mole concept	134 (99.3%)	88 (98.9%)	0.089	0.766
Mass/Mole/Formula units	133 (98.5%)	87 (97.8%)	0.179	0.672
Empirical/Molecular formula	132 (97.8%)	88 (98.9%)	0.369	0.543
Balancing equations (not redox)	134 (99.3%)	87 (97.8%)	0.921	0.337
Net ionic equations	131 (97.0%)	85 (95.5%)	0.365	0.546
Limiting reagent/Excess reagent	132 (97.8%)	87 (97.8%)	0.000	0.990
Theoretical yield/Percent yield	128 (94.8%)	85 (95.5%)	0.055	0.815
Solution stoichiometry (including titrations)	126 (93.8%)	86 (96.6%)	1.149	0.284
Stoichiometry and enthalpy	111 (82.2%)	81 (91.0%)	3.384	0.066
Stoichiometry and gases	118 (87.4%)	83 (93.3%)	1.993	0.158

*Community college $n = 135$; University $n = 89$

Table A7

Pearson Chi Square Values for Energetics Subtopics

Subtopic	Number of respondents (%) covering subtopic		Pearson Chi square value	<i>p</i>
	Community college*	University*		
Heat capacity	127 (94.1%)	83 (93.3%)	0.061	0.805
Calorimetry	125 (92.6%)	81 (91.0%)	0.182	0.670
Heat/Work/Energy	121 (89.6%)	83 (93.3%)	0.869	0.351
Enthalpy/Standard states	128 (94.8%)	84 (94.4%)	0.02	0.888
Hess's law	125 (92.6%)	84 (94.4%)	0.275	0.600
Heat of formation	127 (94.1%)	85 (95.5%)	0.217	0.641
Phase changes/Energy	126 (93.3%)	82 (92.1%)	0.116	0.733
Entropy	121 (89.6%)	78 (87.6%)	0.214	0.644
Free energy/Equilibrium	114 (84.4%)	75 (84.3%)	0.001	0.972

*Community college *n* = 135; University *n* = 89

Table A8

Pearson Chi Square Values for Electrochemistry/Redox Subtopics

Subtopic	Number of respondents (%) covering subtopic		Pearson Chi square value	<i>p</i>
	Community college*	University*		
Oxidation states	132 (97.8%)	86 (96.8%)	0.271	0.602
Oxidizing/Reducing agents	132 (97.8%)	88 (98.9%)	0.369	0.543
Balancing redox equations	123 (91.1%)	77 (86.5%)	1.183	0.277
Galvanic cells: Theory	104 (77.0%)	69 (77.5%)	0.007	0.932
Use/Interpretation of E° tables/Activity series	109 (80.7%)	72 (80.9%)	0.001	0.977
Nernst equation	100 (74.1%)	68 (76.4%)	0.155	0.693
ΔG , E°, K relationships	108 (80.0%)	70 (78.7%)	0.060	0.807
Electrolytic cells/Faraday's law	99 (73.3%)	61 (68.5%)	0.604	0.437

*Community college *n* = 135; University *n* = 89

Table A9

Pearson Chi Square Values for Descriptive Chemistry/Periodicity Subtopics

Subtopic	Number of respondents (%) covering subtopic		Pearson Chi square value	<i>p</i>
	Community college*	University*		
Periodic trends	133 (98.5%)	87 (97.8%)	0.179	0.672
Acidity, reactivity, metallicity	104 (77.0%)	66 (74.2%)	0.243	0.622
Periodic table notation	129 (95.6%)	75 (84.3%)	8.402	0.004
Inorganic/Main group elements	109 (80.7%)	57 (64.0%)	7.792	0.005
Transition elements/Coordination chemistry	76 (56.3%)	36 (40.4%)	5.388	0.020
Organic	76 (56.3%)	28 (31.5%)	13.302	0.000
Modern materials	38 (28.1%)	12 (13.5%)	6.653	0.010
Prediction of reaction products	99 (73.3%)	56 (62.9%)	2.728	0.099

*Community college *n* = 135; University *n* = 89

Table A10

Pearson Chi Square Values for States of Matter/Solutions Subtopics

Subtopic	Number of respondents (%) covering subtopic		Pearson Chi square value	<i>p</i>
	Community college*	University*		
Gases: General properties	132 (97.8%)	89 (100.0%)	2.005	0.157
Gas laws	133 (99.3%)	88 (98.9%)	0.052	0.820
Kinetic molecular theory	134 (99.3%)	83 (93.3%)	6.380	0.012
Liquids: General properties	131 (97.0%)	81 (91.0%)	3.341	0.050
Intermolecular forces	132 (97.8%)	85 (95.5%)	0.915	0.339
Concentration units	134 (99.3%)	89 (100.0%)	0.662	0.416
Colligative properties	126 (93.3%)	77 (86.5%)	2.933	0.087
Solubility principles/Rules	131 (97.0%)	88 (98.9%)	0.832	0.362
Solids/Crystal structures	93 (68.9%)	58 (65.2%)	0.338	0.561
Phase diagrams	123 (91.1%)	75 (84.3%)	2.447	0.118
Classification of matter	129 (95.6%)	78 (87.6%)	4.791	0.029

*Community college *n* = 135; University *n* = 89

Table A11

Pearson Chi Square Values for Experimental Subtopics

Subtopic	Number of respondents (%) covering subtopic		Pearson Chi square value	<i>p</i>
	Community college*	University*		
Use of equipment/Instrumentation	97 (71.9%)	53 (59.6%)	3.669	0.055
Precision and accuracy	119 (88.1%)	78 (87.6%)	0.013	0.909
Preparation and analysis of solutions	103 (76.3%)	66 (74.2%)	0.132	0.710
Experimental design	48 (35.6%)	34 (38.2%)	0.162	0.687
Safety	103 (76.3%)	56 (62.9%)	4.658	0.031
Interpreting data/Graphs	105 (77.8%)	70 (78.7%)	0.024	0.877
Scientific method/Ethics	94 (69.9%)	63 (70.8%)	0.034	0.853

*Community college *n* = 135; University *n* = 89

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