# How Learning Styles, Chemistry Attitudes and Experiences, Confidence, and Demographics Correlate with Academic Success in First and Second Year Chemistry Courses

**Elizabeth Ilnicki-Stone, HBSc, BEd**

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**Faculty of Mathematics and Sciences, Brock University**

**St. Catharines, Ontario**

## Abstract

At Brock University, the Faculty of Mathematics and Science currently has one of the highest percentages of students on academic probation, with many students reporting the most difficulty with Introductory Chemistry in first year and Organic Chemistry in second year. To identify strategies to improve students' performance and reduce the number of students on academic probation, a multi-year research project was undertaken involving several chemistry courses. Students were asked to complete three questionnaires, and provide consent to obtain their final Chemistry grade from the Registrar's Office. Research began at the end of the 2007-08 academic year with CHEM 1P00, and in the 2008-09 academic year, students in the larger CHEM 1F92 Introductory Chemistry course were invited to participate in this research near the beginning of the academic year. Students who went on to take second year Organic and Analytical Chemistry were asked to complete these questionnaires in each second year course. The three questionnaires included the Kolb Learning Styles Inventory (Kolb, 1984) modified to include specific reference to Chemistry in each question, Dalgety, Coll, and Jones' (2002) Chemistry Attitudes and Experiences Questionnaire (CAEQ), and lastly, a demographic survey. Correlations were found between learning style and academic success; concrete learners were not as successful as abstract learners. Differences were noted between females and males with respect to learning styles, academic success, and confidence. Several differences were also noted between those who are the First in the Family to attend university and those who are not First in the Family to attend university.

Dedicated to all my exceptional teachers, including my first teachers, my parents

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## Table of Abbreviations

| | |
|---|---|
| AC | Abstract Conceptualization |
| ACS | American Chemical Society |
| AE | Active Experimentation |
| CAEQ | Chemistry Attitudes and Experiences Questionnaire |
| CE | Concrete Experience |
| ELT | Experiential Learning Theory |
| FFS | First in the Family Student |
| FGS | First Generation Student |
| GPA | Grade Point Average |
| LSI | Learning Skills Inventory |
| NFFS | Non-First Family Student |
| NFGS | Non-First Generation Student |
| RO | Reflective Observation |

## Introduction

At Brock University, the Faculty of Mathematics and Science reports one of the highest rates of students on academic probation after first year. Students are placed on academic probation if their overall average is less than 60% at the end of the academic session or if they have failed at least one course (Brock University Registrar's website, 2010). High attrition rates in science enrolments after first year are also noted in the U.K. (Roberts, 2002). This is of concern as international reviews emphasize the negative effects of decreases in the numbers of science graduates on industry, technological development, and lack of specialist teachers (Dalgety & Coll, 2006b). Science students at Brock University often report the greatest difficulty in first year with their Chemistry course. Of students seeking help at the Student Development Centre's Learning Skills Services (LSS) science drop-in help, over 90% of questions are regarding first year Chemistry assignments, labs, and exam preparation while less than 10% are Math, Biology, and Physics related (LSS Year End Report, Brock University, 2010). Dalgety and Coll note that Chemistry is often viewed by students as "a rather daunting subject" (2006, p. 97). However, many students are very successful in Chemistry at Brock University and enjoy the course.

The relationship between students' abilities in math and academic success in first year Chemistry courses has been well established by many authors such as Cornog and Stoddard (1926) who noted that students who did poorly in university chemistry courses also had very weak mathematical abilities, and were unable to perform stoichiometric calculations. Niedzielski and Walmsley's (1982) work showed that algebraic manipulation was a weakness among those students who failed university Chemistry. Schelar, Cluff, and Roth's (1963) study as well as Lamb, Waggoner, and Findley's (1967) work showed that math scores were highly correlated to achievement in university Chemistry. Similarly the relationship between academic success in high school Chemistry and university Chemistry has been studied by authors such as Everhart and Ebaugh (1925) and more recently Ozsogomonyan and Lofus (1979), which found that a high school background in Chemistry generally correlates positively with academic success in university level Chemistry. Interestingly, where authors such as Scofield (1930), Mamantov and Wyatt (1978), and Tai, Sadler, and Loehr (2005) studied both high school math and high school Chemistry background, it is the ability in math which is a better predictor of university Chemistry success than high school Chemistry courses.

In an editorial in the Research in Science and Technological Education Journal, Chris Botton states that "further robust research regarding learning styles and achievement" in science education is required (2007, p. 151). The goal of this work is to address this need for further research in this field, by identifying characteristics of successful students in first and second year Chemistry courses through study of learning styles as measured by a modified version of the Kolb Learning Styles Inventory, attitudes, confidence, and experiences data through administration of the Chemistry Attitudes and Experiences Questionnaire (CAEQ), and demographic data.

## Kolb's Experiential Learning Theory

### Explanation of the Theory

David Kolb, an American educational theorist, developed the Experiential Learning Theory (ELT), which has been one of the most influential models of learning. Educators use ELT in the classroom with higher education students, to shape curriculum, and to understand the relationship between learning styles and educational choices (Duff, 2004). ELT is unique in that it emphasizes the critical role that experience plays in the learning process. This distinction separates ELT from other learning theories, and provides a holistic model of the learning process (Kolb, Boyatzis, & Mainemelis, 2000). The term experiential differentiates ELT from cognitive learning theories, which tend to emphasize cognition over experience. ELT differs from the transmission model which is based on the idea that pre-existing ideas are simply transmitted to the learner intact (Kolb & Kolb, 2005) and differs from behavioural learning theories that do not consider the learner's own experiences in the learning process. ELT is based on the work of John Dewey, an educational theorist, Kurt Lewin, a social psychologist, and Jean Piaget, a developmental psychologist, and provides a comprehensive theory of learning (Kolb, 1984).

ELT is based on six main propositions: (1) Learning is best thought of as a process, rather than outcomes; (2) All learning is relearning where ideas are drawn out of students to be examined, tested, and refined; (3) Learning requires the use of opposing modes of adaptation: reflection and action, as well as feeling and thinking; (4) Learning involves the complete person, and is not limited to the cognitive processes, but also feeling, perceiving, and behaving; (5) Learning occurs through interactions between a person and their environment; (6) Learning is the process of each person creating knowledge for themselves (Kolb & Kolb, 2005).

Learning is defined by Kolb as "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (1984, p. 41). Grasping the information is insufficient, as something must be done with that experience to result in learning. Transformation cannot occur without an experience, and so both are required for learning to occur.

ELT involves two contrasting modes of grasping experience: Concrete Experience (CE) and Abstract Conceptualization (AC), as well as the two contrasting modes of transforming experience: Reflective Observation (RO) and Active Experimentation (AE).

CE involves grasping information by experiencing the concrete, tangible qualities of the world through the use of our senses and reality, while AC involves grasping new information through symbolic representation. Rather than experiencing information through the senses, AC involves thinking about, analyzing, or planning. On the continuum of transforming experience, AE involves being physically involved in the process while RO involves carefully watching others involved in the experience and reflecting on the results.

By plotting the modes to grasp experience (perception continuum) along the y axis, and the modes to transform experience (processing continuum) along the x axis, four quadrants corresponding to Kolb's learning styles of Diverging, Assimilating, Converging, and Accommodating are formed as shown in Figure 1.

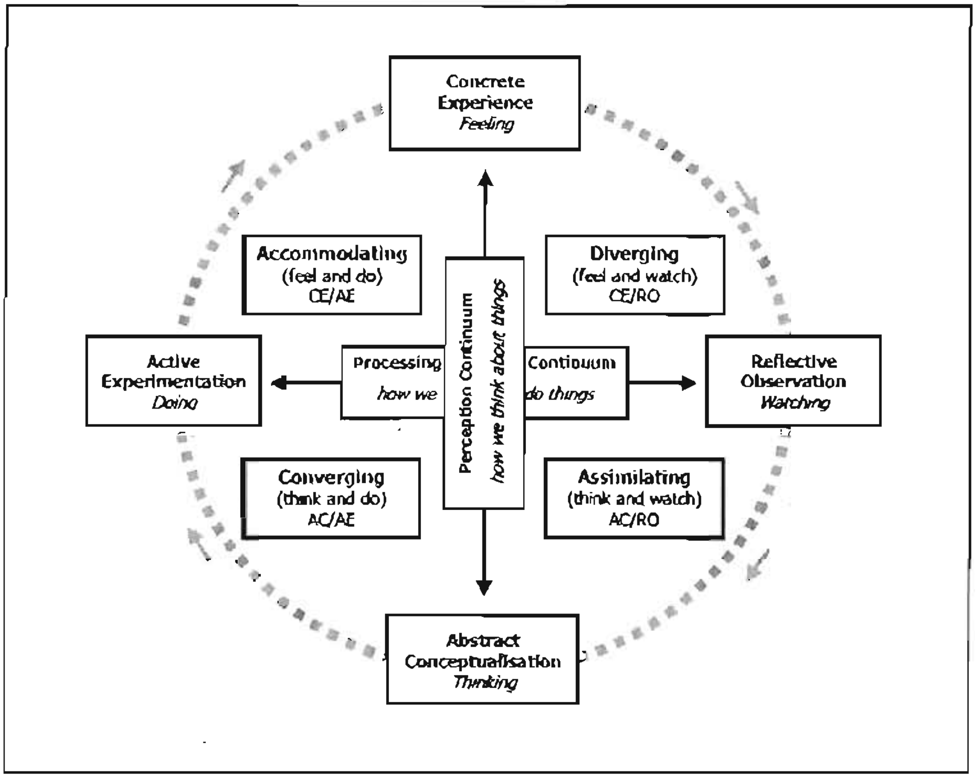


Figure 1. Kolb's learning styles. Adapted with permission from Kolb, 1984. Copyright 1984, Prentice-Hall.

Through our life experiences, the demands of our present environment, and heredity, each person develops a preferred style of adapting to new learning situations by choosing between concrete or abstract methods, and between action or reflection in characteristic ways. These patterned ways are called learning styles (Kolb et al., 2000). These styles are not fixed, but rather are preferences that vary with the situation presented, and can change over time (Kolb, 1984).

## Kolb's Four Learning Styles

The Diverging learning style involves learning where experience is grasped through a Concrete Experience, and transformed through Reflective Observation. The learner must be able to reflect on that which they experienced in a concrete form. In Chemistry this could involve a student building molecular models of a trigonal bipyramidal shape and reflecting on why lone pairs occupy the equatorial positions rather than the axial positions. In the Assimilating learning style, the experience is grasped through Abstract Conceptualization and transformed through Reflective Observation. The learner must possess and use analytical skills to conceptualize the experience. An example of this is understanding the concept of hybridization of molecular orbitals through visualization of the abstract concept and reflecting on the properties of the various types of overlap and how sigma bonds differ from pi bonds in terms of their energy.

The Converging learning style requires that the learner use Active Experimentation to grasp the experience, and transform it through Abstract Conceptualization. The learner must possess the required decision-making and problem-solving skills in order to use the new ideas gained from the experience. A student performing a Coffee Cup Calorimetry experiment would actively participate in the experiment, but would require the ability to think abstractly to understand what is occurring and be able to do the required calculations.

In the Accommodating learning style, the learner grasps the experience though Concrete Experiences and transforms it through Active Experimentation. In order to learn, the person must be willing to be actively involved in the experience. In a laboratory setting, a student might be permitted to very quickly put their hand into liquid nitrogen, and then actively experiment with putting filled balloons into liquid nitrogen to watch them compress, or put rubber tubing into the liquid nitrogen and then watch it shatter when hit against the lab bench.

Learning occurs best when the learner experiences all four modes in each learning cycle. Although the learning cycle can begin at any of the four quadrants, most learning begins with an immediate or concrete experience. This experience serves as the basis for observations and reflections. These observations and reflections are assimilated and transformed into abstract concepts and theories. These theories present new implications for action, which can be actively investigated to serve as the basis for a new cycle of learning (Kolb et al., 2000). This learning cycle is summarized in Figure 2.

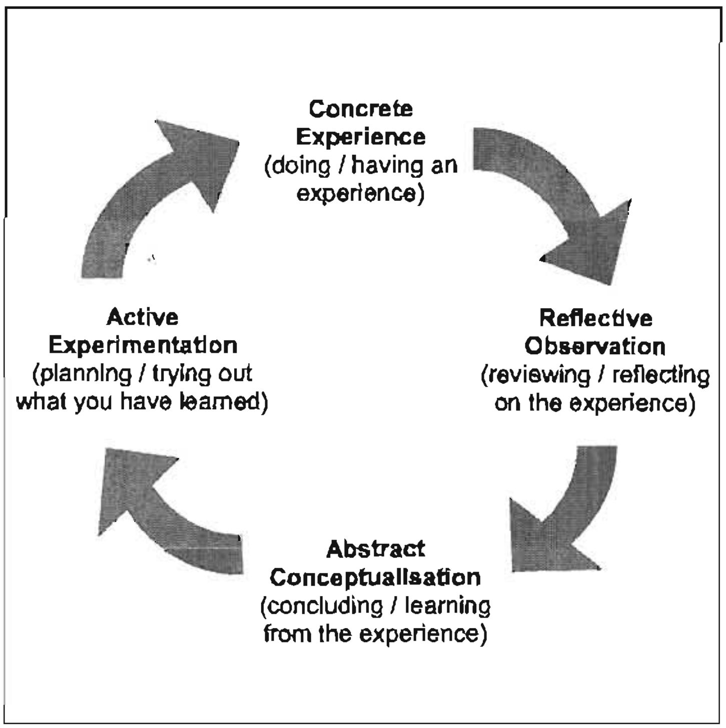


Figure 2. Kolb's Experiential Learning Cycle. Adapted with permission from Kolb, 1984. Copyright 1984, Prentice-Hall.

In order for this learning cycle to be successful, the learner must be open to, and skilled in all areas of grasping and transforming knowledge. The learning cycle is more accurately described as a learning spiral since, following each cycle of learning, the learner is changed and better able to approach the next cycle of learning.

**ELT and Neuroscience Research**

Research by Zull (2002) suggests that ELT is related to the process of brain functioning. The sensory cortex receives sensory input from the five senses; this relates to Concrete Experience. The temporal integrative cortex makes sense of the sensory input which is Reflective Observation. The frontal integrative cortex analyzes the sensory input and develops a plan of action, which is Abstract Conceptualization. Finally, the premotor and motor cortex carry out the plan of action in Active Experimentation (Figure 3).

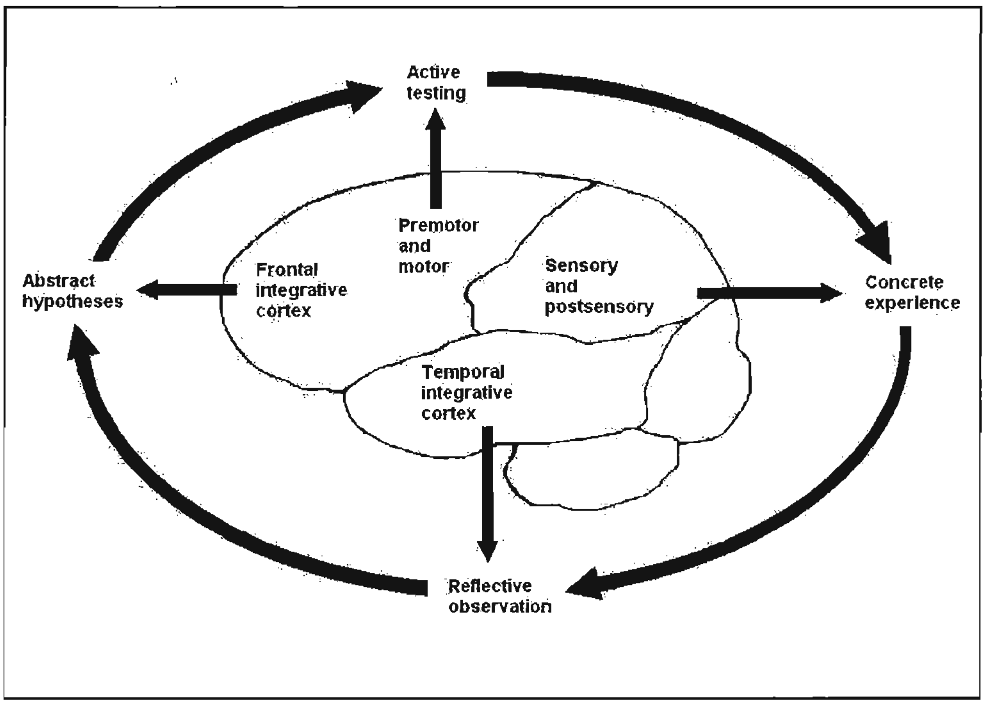


Figure 3. The Experiential Learning Cycle and regions of the cerebral cortex. Adapted with permission from Zull, 2002. Copyright 2002, Stylus.

Zull argues that the learning cycle is based on the brain's structure: concrete experiences come in through the sensory cortex, reflective observations require the integrative cortex at the back, the creation of abstract concepts occurs in the frontal integrative cortex, and the motor brain is involved in the active testing.

## Kolb's Learning Styles Inventory

### Background of the Kolb Learning Styles Inventory

Kolb's work not only offers a theory on the learning cycle through experiential learning, but also offers a tool to identify individual learning styles. The Learning Style Inventory (LSI) was developed in 1971 to assess individual learning styles (Kolb, 1984) and to help individuals identify the way they learn from experience (Kolb & Kolb, 2005). The LSI is not meant to be a predictive psychological test, such as an IQ test is, but rather a self-assessment exercise to understand how one learns.

### Description of the Kolb Learning Styles Inventory

The LSI is written at a seventh grade reading level (Kolb & Kolb, 2005). There are 12 sentence stems with four possible answers, each of which corresponds to one of the four modes of learning: CE, AC, RO, and AE. Respondents rank the four possible answers, with no ties in scores allowed. This forced-choice format is considered crucial to ELT and is the primary purpose of the instrument since Kolb believes that learning involves resolving the tension between the extremes in each dimension: AC vs. CE and AE vs. RO (Kolb, 1984). The modified version (Appendix D) used in this research, asks the person completing the survey to think of a situation when they are learning Chemistry as opposed to any other learning situation. The original LSI does not ask the person completing the survey to think of a specific type of learning situation, which could result in poor test-retest reliability if the person thinks of two different learning situations on the two occasions.

The total for each of these learning modes is summed, and the AE–RO score identifies the degree to which Active Experimentation is favoured over Reflective Observation. The AC-CE score determines the degree to which Abstract Conceptualization is favoured over Concrete Experience. AE-RO and AC-CE scores are then plotted to determine what quadrant (Diverging, Assimilating, Converging, or Accommodating) the data point falls in, identifying the individual's preferred learning style (Kolb & Kolb, 2005). Since Kolb's learning styles are not fixed personality traits, but rather relatively stable patterns of behaviour based on an individual's background and experiences, they are more accurately described as learning preferences, rather than styles, and vary with the learning task. Since learning style preferences vary with the learning task, the modified Kolb LSI in this research asks the person to think of a situation when they are learning Chemistry specifically, or in the case of the second year courses, Organic Chemistry or Analytical Chemistry.

**Characteristics of Kolb's Learning Styles**

**Diverging Learning Style**

Those with a Diverging learning style prefer Concrete Experiences to grasp information, and Reflective Observation to process the experience. Divergers have the ability to view situations from many different perspectives, are imaginative, and do well in situations that require the generation of ideas. Divergers like to gather information, and approach new situations by observing rather than taking action. They tend to be interested in others, and are often emotional. In formal learning situations, Divergers prefer to work in groups, brainstorm, discuss ideas, receive personalized feedback, and work on open-ended tasks (Kolb, 1984).

### The Role of the Instructor in Working with Divergers

The instructor's role is to be a motivator who can make the information applicable, show interest in the student's experiences, and encourage the student. Providing an understanding of the relevance of the topic can be quite helpful, as Divergers seek to answer the question "Why is this important?" (Towns, 2001). Relating information to past experiences, students' interests, or career objectives can be beneficial as it connects the new ideas to information that the student already has.

### Assimilating Learning Style

Those with an Assimilating learning style tend to grasp information through Abstract Conceptualization and transform it through Reflective Observation. Assimilators are able to understand a wide range of information and assimilate it into a concise, logical integrated form. They are more interested in abstract theories and concepts than they are in people. Assimilators are often extremely theoretical and not always able to determine the practical applications of their ideas (Kolb et al., 2000). The question Assimilators ask is "What is the concept?" (Towns, 2001). In formal learning situations, Assimilators enjoy readings, lectures, exploring analytical models, designing experiments and projects, and being given time to process information before having to act (Kolb, 1984). Self-paced materials such as on-line materials allow assimilators to reflect and take in information at their own pace.

Many mathematicians and theoretical chemists are assimilators, and this is a common learning style in research and development departments (Kolb, 1984).

**The Role of the Instructor in Working with Assimilators**

For Assimilators, the instructor functions as an expert, providing information in a logical manner, and is a resource if the students have questions (Towns, 2001). This has been the traditional role of Chemistry faculty, and a strong component of many Chemistry professors' teaching styles (Towns, 2001).

**Converging Learning Style**

Those with a Converging Learning Style prefer Abstract Conceptualization and Active Experimentation. Convergers have great skill at determining practical applications for ideas and theories. They are good problem solvers, especially when there is a single correct answer, and enjoy making decisions in a systematic way (Kolb et al., 2000). The primary question Convergers ask is "How is the concept applied?" (Towns, 2001). Convergers require opportunities to work actively on tasks. Convergers prefer technical tasks to working with others, and often choose to specialize in the physical sciences. These types of learners do well in situations where there is one correct answer. They also enjoy experiments, guided inquiry, simulations, and practical applications of theory (Towns, 2001). These types of activities help Convergers develop their problem solving techniques so that they can apply them to other situations.

**The Role of the Instructor in Working with Convergers**

Instructors act as guides or coaches providing opportunities for the students to be actively involved in the learning process and to develop and extend their skills. They provide feedback to the students as needed (Towns, 2001).

**Accommodating Learning Style**

Those with an Accommodating Learning Style prefer to grasp information through Concrete Experience and Active Experimentation. People with this learning style prefer hands-on experiences to carry out plans, and enjoy new challenges. Accommodators tend to ask "What are the possibilities?" (Towns, 2001). Accommodators have a tendency to be more impulsive and less analytical in their approach, often relying on their feelings or senses, rather than using logical analysis. They rely heavily on other people for information, rather than their own analysis, and often use trial and error methods to solve problems (Kolb,1984). They enjoy working with others, and are good at adapting to new situations. Their strengths are in risk-taking, setting goals, field-work, and testing new approaches. Accommodators need opportunities to apply learned concepts to new situations, especially real-life situations, and enjoy self-discovery (Kolb et al., 2000).

**The Role of the Instructor in Working with Accommodators**

The instructor's role for working with Accommodators is to provide maximum opportunities for the student to discover information and express their understanding through open-ended lab activities and open-ended problem solving (Towns, 2001). Application of learned concepts to real-life issues is of particular interest to Accommodators. Placing a higher value on performance based skills, such as through the evaluation of laboratory skills, gives value to the learning strengths of Accommodators (Towns, 2001).

**Comparison of Learning Styles**

A summary of tasks favoured by each learning style is summarized in Figure 4 including the role of the instructor. Also included in Figure 4 is the primary question each learning style seeks to answer.. These questions can guide an instructor in preparing a lecture or laboratory to meet the needs of all four learning styles.

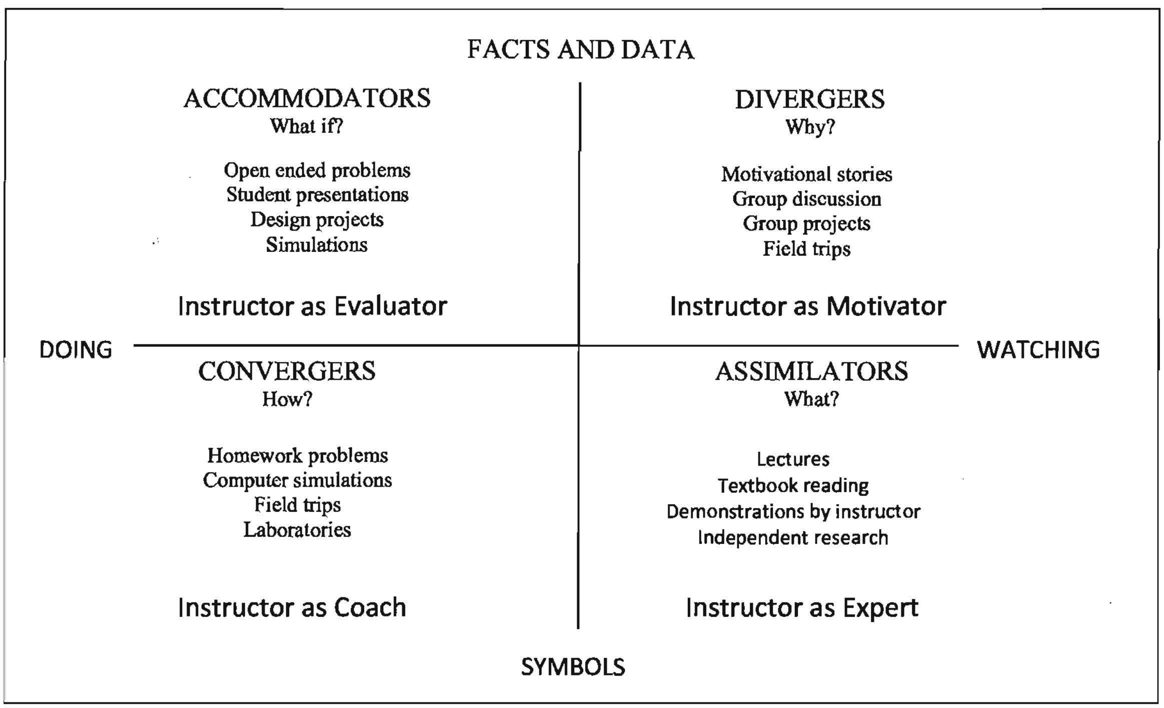


Figure 4. Preferred learning activities for each learning style, primary question each learning style seeks to answer, and role of the instructor. Adapted with permission from Montgomery and Groat, 1998. Copyright 1998, University of Michigan.

Figure 5 shows instructional activities tailored to each dimension of the Kolb LSI. In order to produce a complete learning cycle, the instructor would choose a technique from each category and guide students through each activity in order. For example, students could collect lake water samples through field-work (CE), brainstorm different techniques to perform the analysis of lead content (RO), be given a lecture on spectroscopy required for the lab (AC), and finally, perform the laboratory exercise (AE).

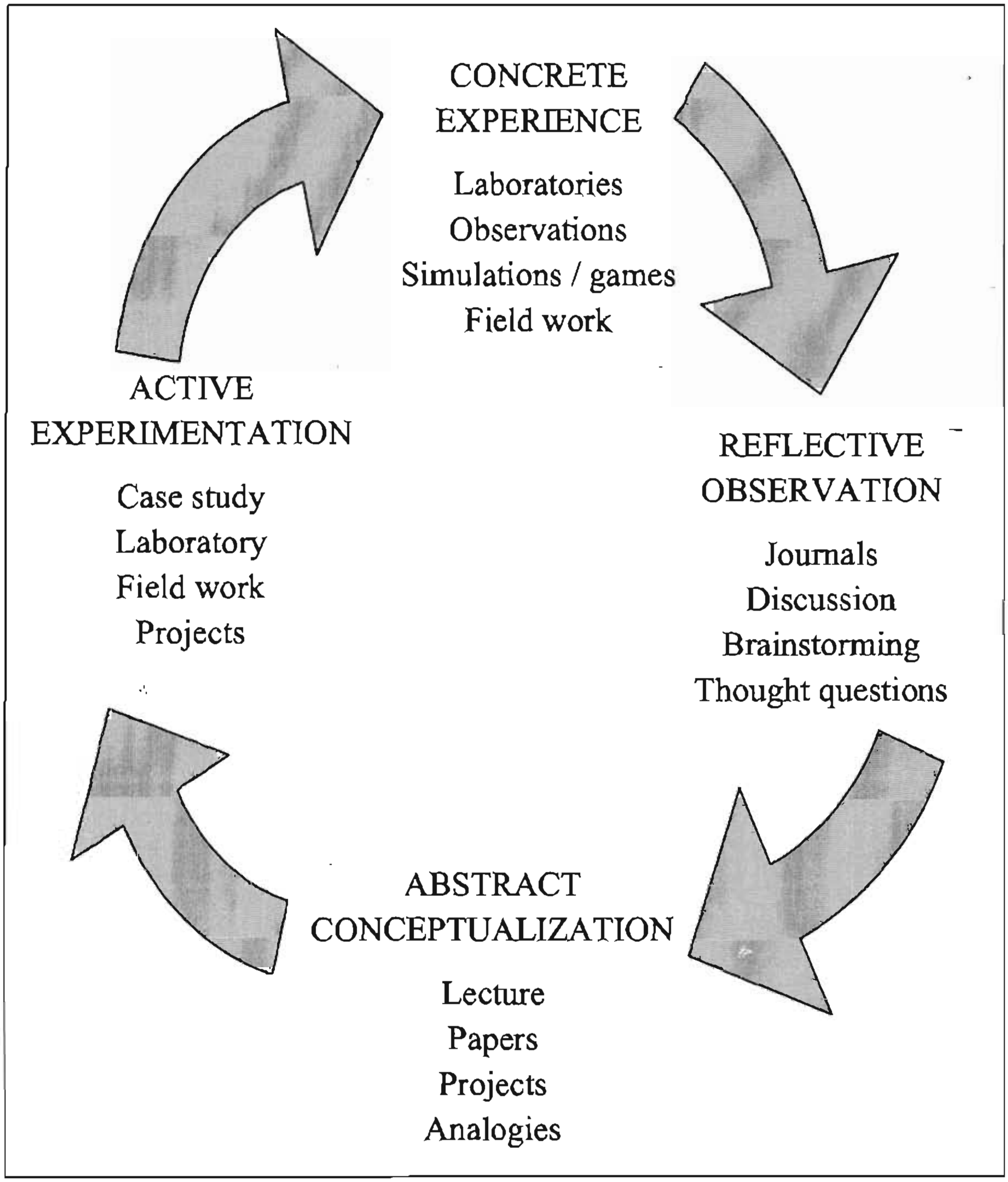


Figure 5. Instructional activities tailored to each dimension of the LSI. Adapted with permission from Svinicki and Dixon, 1987. Copyright 1987, College Teaching.

## Opposing Learning Styles

As well as differences in preferred modes of instruction, the four learning styles vary in terms of their goals in processing information. For Divergers, there is one input of data, but many outputs. This is in contrast to Convergers who take in a great deal of data, but converge it into one answer. Assimilators take many ideas and create one theory, while Accommodators take one theory and apply it to several situations (Beck, 2008).

## Studies Using the Kolb Learning Styles Inventory

A study by Jones, Reichard, and Mokhtari (2003) asked first-year students to complete four versions of the Kolb LSI, which were modified in each case for the disciplines of English, mathematics, science, and social sciences. The researchers' goals were to determine if there were learning style differences between genders, and whether students had different preferred learning styles, depending on the subject matter. Their results did not find differences between genders, but found that there were differences among the students with respect to their learning styles in approaching the different disciplines. The students believed that different modes of learning were required depending on the discipline, and were able to "style-flex" to adapt to the situation, which is consistent with previous research by Kolb (1984). Eighty-one percent of students showed a preference for different learning styles depending on the subject matter. Science learning showed the highest scores among the four disciplines studied for Active Experimentation mode, meaning that students most preferred to learn science through active involvement (Jones, Reichard & Mokhtari, 2003). Of the students studied, the learning styles for science were determined to be: Divergers 23.3%, Assimilators 34.0%, Convergers 27.2% and Accommodators 15.5%.

Jones, Reichard, and Mokhtari (2003) also hoped to determine if learning styles correlated to overall academic average for first year students. They determined that Assimilators had the highest average of 3.40 on a 4 point scale, followed by Convergers (3.21), then Divergers (2.94) and Accommodators (2.67). This suggests that AC correlates to higher average grade scores than CE, and RO correlates to higher average scores than AE. Although Kolb (1984) stresses that none of the learning styles is better than any other, the traditional lecture style of post-secondary education, especially in the sciences, likely benefits those who prefer abstract learning.

Lawson and Johnson (2002) studied post-secondary students learning biology. The material was taught in a method favouring concrete learners (inquiry based) to one group and with a method favouring abstract learners (traditional expository method) to another group. It was hypothesized that according to Kolb's theory, those who preferred a feeling style of learning would achieve higher scores than thinkers where the instructional method was largely group work, while those who preferred a thinking learning style would achieve better grades in a more traditional expository learning environment (Figure 6).

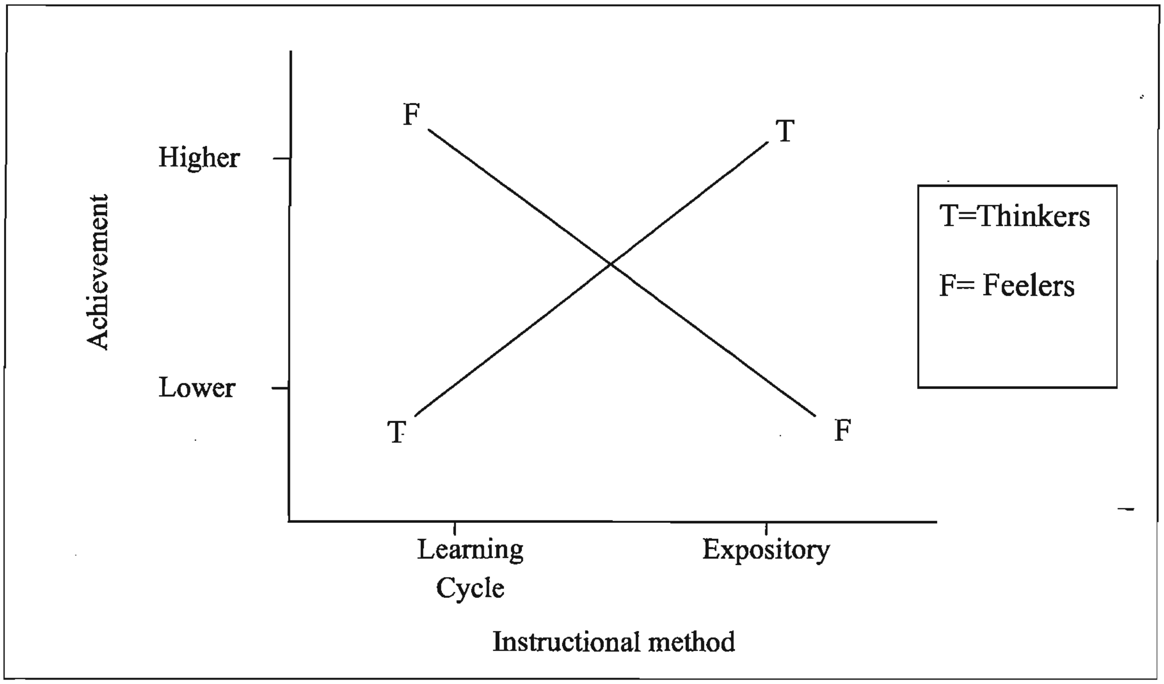


Figure 6. Predicted patterns of achievement based on instructional method, based on Kolb's theory. Adapted with permission from Lawson and Johnson, 2002. Copyright 2002, Studies in Higher Education.

However, developmental theory would argue that thinkers are more advanced in their processing than feelers, and would outperform feelers regardless of instructional method as shown in Figure 7.

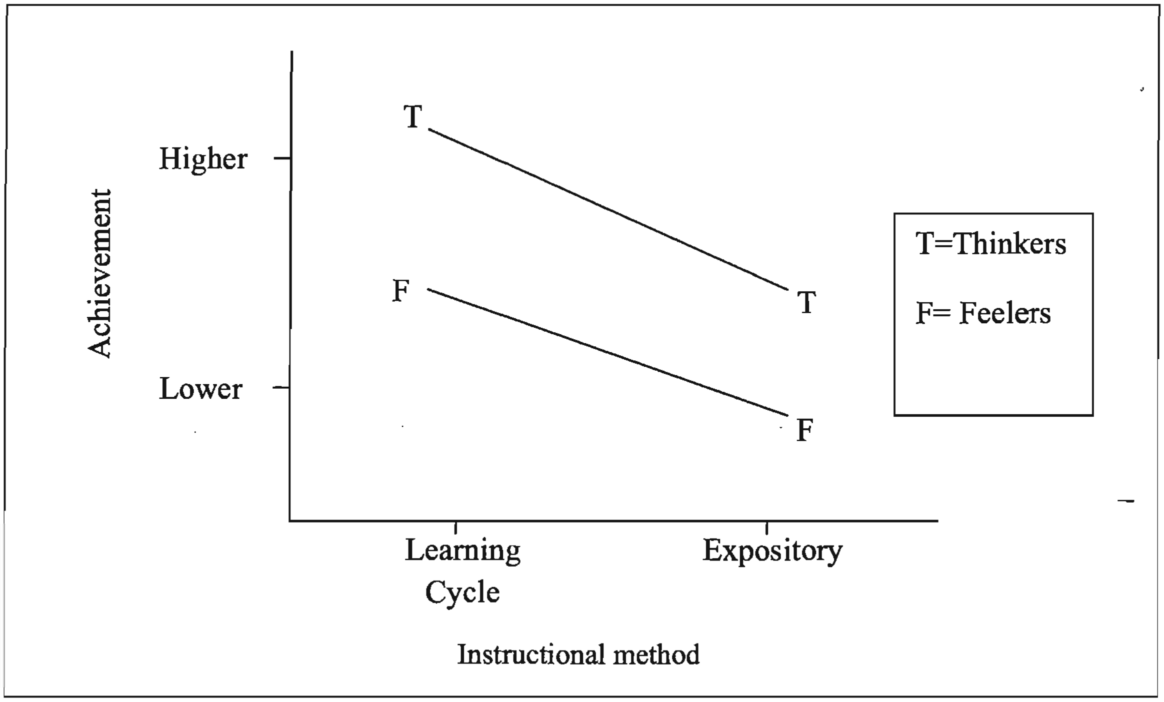


Figure 7. Predicted pattern of achievement based on developmental theory. Adapted with permission from Lawson and Johnson, 2002. Copyright 2002, Studies in Higher Education.

When methods such as inquiry and group work, favoured by concrete learners (Kolb, 1984), are the modes of instruction, students performed better than when taught in a traditional expository format (Figure 8). Interestingly, those who preferred an abstract learning style also performed better when an inquiry style model of instruction was employed (Figure 8). Use of inquiry based instruction resulted in higher course achievement for both those favouring a concrete learning style and those favouring an abstract learning style. However, regardless of the mode of instruction, abstract learners did achieve higher scores on tests than concrete learners (Figure 8). Lawson and Johnson (2002) believe that learning science concepts requires higher order deductive reasoning, and little in the way of feeling. Therefore, thinkers would outperform feelers regardless of instruction style in learning scientific material. However, knowledge of, and incorporation of learning style instruction led to higher scores in both groups.

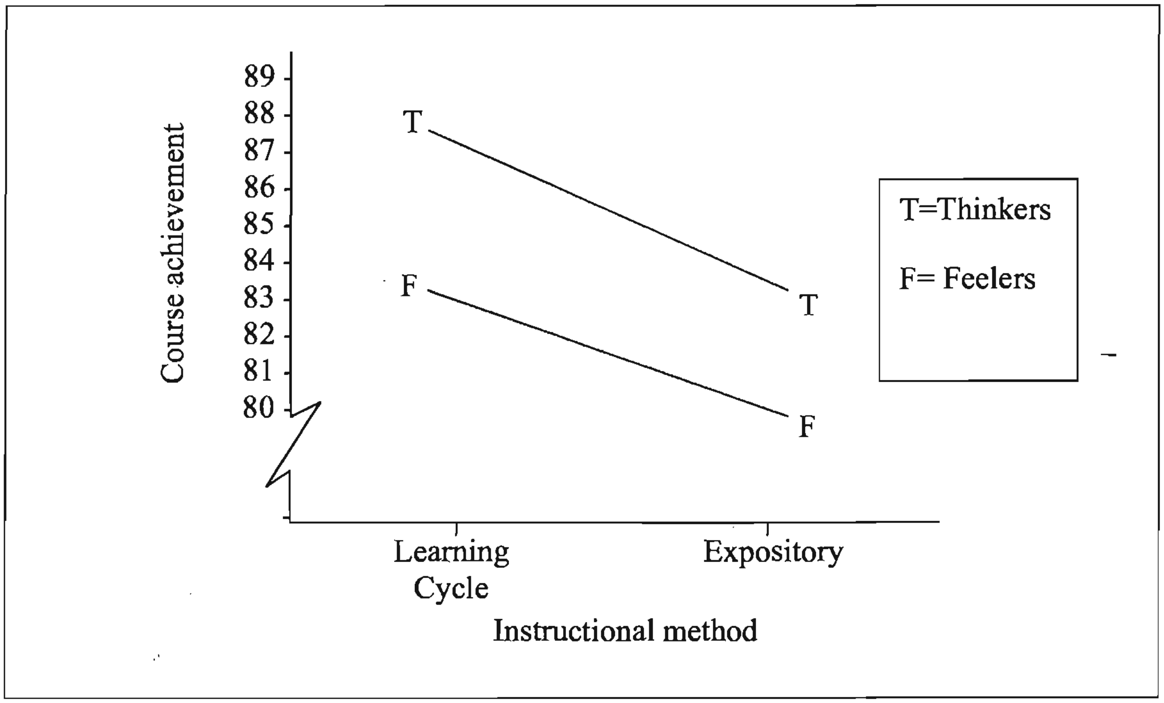


Figure 8. Pattern of course achievement (%) by thinkers (T) and feelers (F) based on instructional method. Adapted with permission from Lawson and Johnson, 2002. Copyright 2002, Studies in Higher Education.

The results of the work by Lawson and Johnson (2002) show that thinkers outperformed feelers regardless of teaching style, but that scores for both groups were higher when instructors were aware of experiential learning theory and incorporated it into their curriculum. This research was limited to students enrolled in a non-majors biology course.

**Learning Styles and Academic Success**

While Kolb (1984) argues that there is not one learning style that is better or worse than the others with respect to helping students succeed academically, he also contends that students with certain learning styles do better in various disciplines. As well, Kolb's own research on a normative sample of 6977 people shows that those with higher education levels have a preference for abstract thinking, as compared with those with less education (Figure 9).

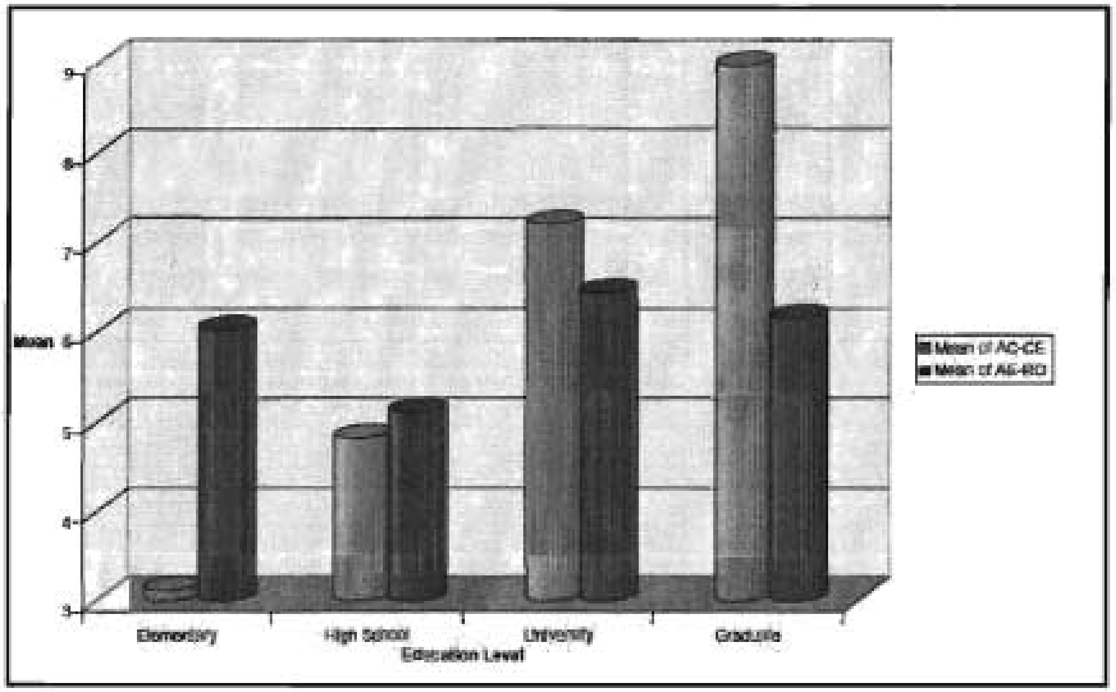


Figure 9. Scores on AC-CE and AE-RO by level of education. Reprinted with permission from Kolb and Kolb, 2005. Copyright 2005, Academy of Management Learning & Education.

However, these results could be due to the type of testing that often occurs in the education system where one correct answer is sought such as with mathematics and science calculations or in multiple choice and short answer questions. Concrete thinkers are skilled at divergent thinking and viewing things from multiple perspectives. However, formal education often asks students to take information and formulate one answer. Students are rarely asked to provide multiple perspectives or interpretations, other than in the humanities or arts. Boyatzis and Mainemelis (2000) argue that differences in achievement among the learning styles may be a function of the type of assessment chosen. Their research suggests that educators must employ diverse assessment strategies to measure student abilities. For example, Convergers tend to do extremely well in questions that require data to be substituted into equations to obtain one correct answer, such as problems involving gas laws. Assimilators tend to excel at questions that require theoretical understanding of intangible concepts such as predicting how introduction of a gas into a closed system would affect the overall pressure of the system. Again, there is one correct answer. However, Divergers who are skilled at viewing topics from many perspectives tend to not get opportunities in testing situations to show their learning strengths. Similarly, Accommodators tend to excel at assessments such as laboratory skills, which are often not evaluated.

Albergaria-Almedia, Teixeira-Dias, Martinho, and Balasooriya (2010) studied 100 students in a chemistry course designed for first year science and engineering students and observed that the top seven students all had an assimilating learning style. These results do concur with those of Kolb (1984) suggesting that the typical learning style of a chemist is assimilating, since those with this learning style have the ability to create theoretical models, compare alternatives, define problems, and formulate hypotheses. This learning style also tends to have a deep style of understanding, rather than more superficial learning such as memorization. In interviews of the seven students with the highest grades, Albergaria-Almedia et al., (2010) found that all of the highest achieving students commented that memorization and application of knowledge are important, but that understanding in the learning process is crucial. These researchers suggest that instructors take small pauses during lecture to allow students to discuss concepts with those around them and then take the time to answer the students' questions. These pauses allow Assimilators time to process the concepts and Divergers the opportunity to discuss with others. As well, students are encouraged to submit questions in written form to the instructor, which will be answered either through an on-line forum or during the next class.

Hargrove, Wheatland, and Ding (2008) studied the Kolb Learning Styles of engineering students. Their results are listed in Table 1. Hargrove et al. (2008) noted that in engineering, Convergers had the highest mean GPA, while Divergers the lowest.

Table 1. Kolb's Learning Styles and GPA in Engineering Students

| Students (n = 232) | | | Course Grade | |
|---|---|---|---|---|
| | | | Mean | S. D. |
| Accommodator | 33 | 14.22% | 2.6735 | 0.9040 |
| Assimilator | 103 | 44.40% | 2.6384 | 0.8200 |
| Converger | 55 | 23.71% | 2.7869 | 0.7904 |
| Diverger | 41 | 17.67% | 2.4048 | 0.6815 |

*Note.* Adapted from Hargrove et al., 2008 with permission. Copyright, 2008, Journal of STEM Education. Means and standard deviations are reported by the authors to a higher degree of precision than warranted by the data.

**Learning Styles and Field of Study**

Kolb (1984) argues that students succeed academically when the learning environment matches their learning style. Research using the LSI has found significant relationships between learning style and field of study (Kolb, 1984) as well as career choice. Certain majors predominate in particular learning styles: engineers tend to be Convergers or Assimilators, Chemistry majors tend to be Assimilators, natural science majors in the fields of medicine, Biology, physical science, and Mathematics tend to be either Convergers or Assimilators, while those studying Psychology tend to be Divergers (Kolb, 1976).

In a study by Kolb (1976), eight hundred practicing managers and graduate students in management were asked to complete the Kolb LSI and report their undergraduate major; six hundred and thirty people participated. Average Kolb LSI scores were obtained for each undergraduate major (Figure 10). The x and y axes are drawn using the mean score for AC-CE and AE-RO rather than through 0,0. However, the unequal group sizes of undergraduate studies results in the position of the axes being strongly determined by the scores for the Engineers as they make up over one third (37%) of the sample. Plotted in the traditional format, with axes at 0,0 would result in all participants being classified as Convergers since the averages for all undergraduate majors were positive AC-CE and AE-RO scores.

Since all participants in this study were either practicing managers or graduate students in management, and the Kolb LSI did not specify a specific learning situation, it is possible that those who completed the questionnaire thought of learning situations which were related to their careers, which would result in the homogeneity of the results.

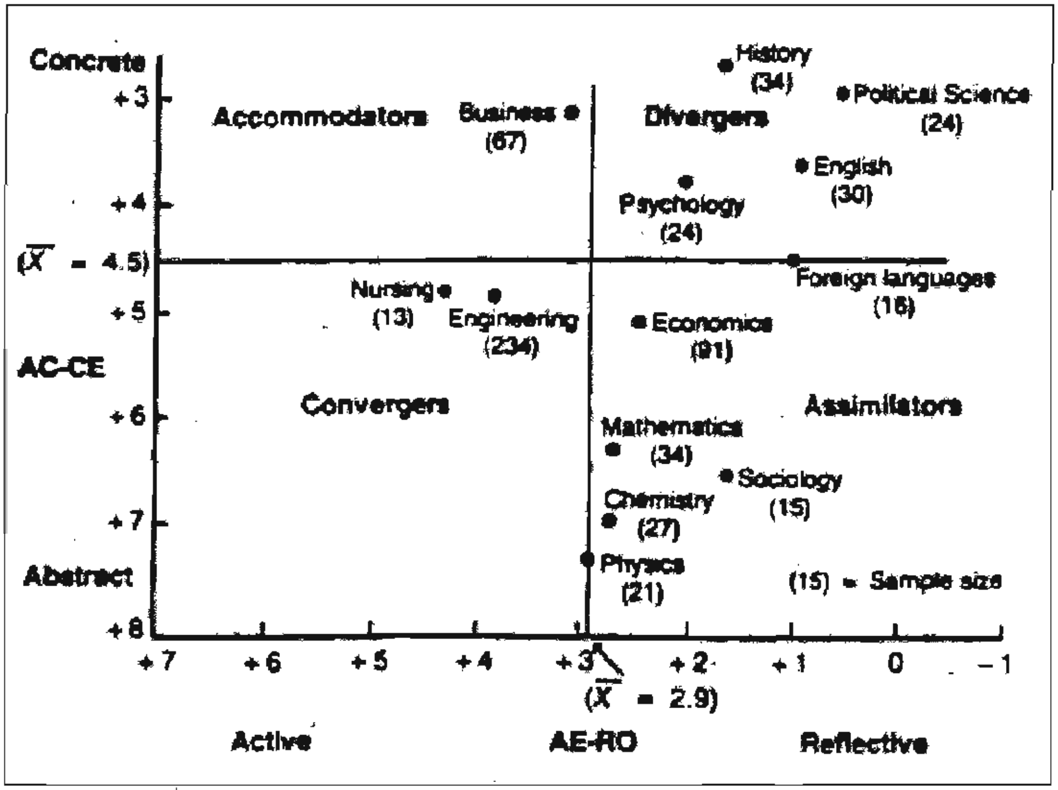


Figure 10. Field of undergraduate study as reported by 630 practicing managers and graduate students in management. Reproduced with permission from Kolb, 1976. Copyright 1976, California Management Review.

**Studies of Chemists**

Studies of scientists as learners, including chemists, had been conducted by Kolb (1976), but Smedley (1987) decided that there was great value in studying the learning styles of professional chemists separately from other scientists since skills required in the various fields of science can be vastly different. Four hundred and forty-one members of the American Chemical Society (ACS) living in the United States completed questionnaires, including the Kolb LSI. The sample mean for the ACS members for AE-RO was 4.46 (Smedley, 1987), which was higher than the mean for Kolb's adult population of 2.74 determined by a sample of 6977 participants (Kolb et al., 2000). The ACS sample mean for

AC-CE was 5.41 which is higher than Kolb's sample mean of 3.06. This result suggests that chemists, as a group, tend to prefer AE and AC more than the typical adult population to a small degree (Figure 11). However, information on variance is not provided for Smedley's (1987) data and therefore, statistical analyses could not be done to determine if the difference is statistically significant.

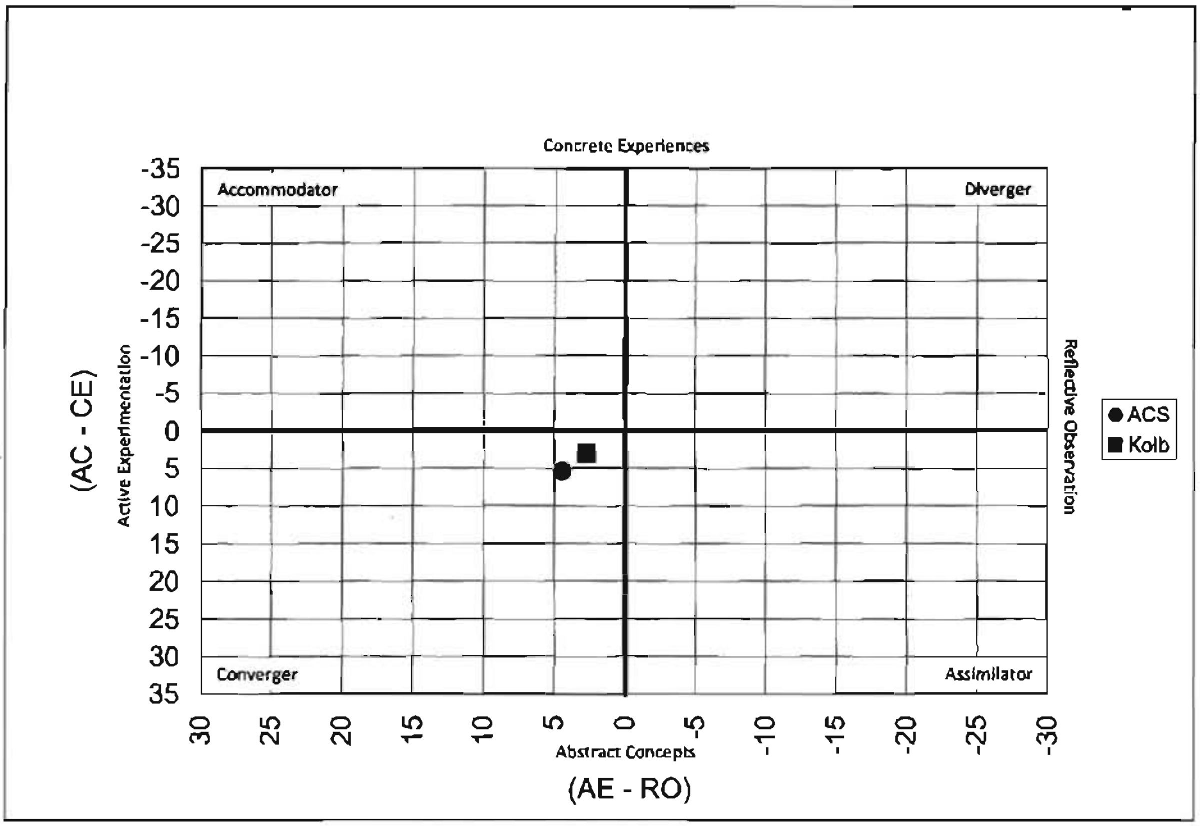


Figure 11. The centroid of the learning styles of 441 ACS Chemists (Smedley, 1987) compared to the centroid of Kolb's population of 6977 participants (Kolb et al., 2000).

Smedley's findings are consistent with Kolb's learning theories (1984). Smedley also determined that older chemists tend to be more inclined towards RO and AC than younger chemists (1987). This supports Kolb's research (1984), which showed an increased preference for abstraction with age as measured by the AC-CE value. Montgomery and Groat (1998) reported that, with time, science students become more analytical and less creative. While analytical skills are important, creativity in the sciences is also essential and is to be encouraged. Male and female chemists were not found to have significantly different learning styles (Smedley, 1987).

**Use of Learning Styles in the Classroom by Students**

Kolb describes the role of the LSI as a tool to "make the student self-renewing and self-directed; to focus on integrative development where the person is highly developed in each of the four learning modes; active, reflective, abstract, and concrete (1984, p. 203). Hargrove et al. (2008) state that knowing their own learning style is helpful to students so that they can understand how they learn and what skills they need to develop in order to adapt to all learning situations to reach maximum outcomes. Sharp (2001) argues that a knowledge of learning style theory helps students better understand their learning problems and improved understanding often results in finding solutions to resolve learning conflicts. Honey and Mumford (2000) contend that the most effective problem solvers are good learners who can adapt to a range of environments. With this objective in mind, knowledge of individual preferences can act as a focus for personal development.

Vancleaf and Schkade (1987) view the LSI as a tool to encourage self-development within an academic field. This self-development arises from the knowledge of different learning styles and the stages of the learning process, rather than being assigned to a given learning style. If students do not have the purpose of the LSI explained, and believe that they are only capable of a certain type of learning, this presents the risk that students might believe that they are limited to only one way of learning, as opposed to understanding that learning styles are preferences and depend on the learning task.

**Use of Learning Styles Information by Educators**

The task of optimizing learning environments to engage students and effectively support all learners is extremely challenging. Sharp (2001) states that people generally prefer to send information in the way that they prefer to receive it. Montgomery and Groat (1998) argue that if instructors are not reflective about their teaching practices, they will simply teach how they learn, assuming that this is the best method for all students. In the Faculty Guidebook, James Hadley, Director of Education at Hamilton College (2009) advises that it is beneficial for instructors to recognize and understand the various learning styles and learn how to best utilize this information to promote learning among all students. Learning styles are defined as the ways students respond to stimuli in a learning context, and their characteristic way of acquiring and using information (Yeung, Read & Schmid, 2006).

Towns (2001) argues that the most common teaching methods of Chemistry including formal lectures, instructor-led problem solving and demonstrations, guided labs, and computer simulations work well for Assimilators who ask "What is the concept?" and Convergers who seek to know "How is it applied?". However, Divergers who need to know "Why is this important?", and Accommodators who ask "What are the possibilities?" could become frustrated and either switch out of science or drop out of university. Tobias' work shows that there is a great deal of evidence of the mismatch between some students' preferential learning styles and those traditionally found in the physical sciences. Towns

(2001) argues that providing a wider range of teaching styles, especially in introductory courses, may help attract and retain undergraduate majors in the physical sciences, while they develop the learning skills more prevalent to their particular disciplines. The goals of instruction are to teach in multiple learning styles, and also to help students develop their skills in both their preferred and less preferred learning styles.

Hermon (2007) believes that if educators have knowledge of how students prefer to learn, instruction can be geared such that there is individualized instruction to produce students, competent in all four learning styles, who are more balanced and integrated learners. Kolb (1984) originally proposed a model that had the educator match their teaching style to the learners' preferred style of learning, but later concluded that there was merit is deliberately creating a mismatch so that students could develop as learners in ways they would normally avoid. Rush and Moore (1991) observed that matching teaching styles to the students' learning styles does not prepare them for situations in which they will be required to work outside of their preferred learning styles. Hadley (2009) encourages faculty to help students improve academic performance using non-preferred learning styles because life after university requires students to possess a range of competencies.

Loo (2004) recommended that educators use a variety of methods in order to teach to the broad range of learning styles. Recent research on teacher effectiveness shows that teachers who are able to use a variety of teaching strategies are most effective (Darling-Hammond, 2000). Hermon (2007) cites the importance of developing teaching techniques which address all learning styles by providing a variety and balance in content and delivery. Methods must also focus on improving motivation and attentiveness, which will likely result in improved retention rates for students. Research by Felder (1993) has shown that alignment between a student's learning style and the instructor's mode of teaching results in improved recall and understanding, and better attitudes among the students. Although students may learn best and be more comfortable when there is a match between instruction and learning styles, students must learn to work outside their preferred styles and learn to adapt since they will not be able to select their mode of instruction (Felder, Felder, & Dietz, 2002). Therefore, a range of instruction styles provides the student with some information in their preferred mode to increase motivation, but also provides instruction in alternate modes to allow them to learn how to adapt to situations outside of their preferred style.

Where the examination of learning styles of both student and lecturer has been carried out, there was clear evidence that the educational experience had been improved. Awareness of the existence of different learning styles and sensitive adjustment by the teacher as a result tended to change the teaching environment away from the traditional lecture. The development of a learning vocabulary helped create productive discussions between teachers and students, and this self-awareness and metacognition enabled students to improve how they learned (Hermon, 2007).

**Differences between Females and Males in Learning Styles**

Kolb and Kolb's (2005) study of a normative sample of 6977 individuals (50.4% female, 49.4% male, 0.2% not given) ranging in age from 17-75 and including a wide variety of employment fields as well as college students, showed that males had statistically significantly higher scores in AC-CE than women, 8.75 with a standard deviation of 11.55 for males as compared to 4.94 with a standard deviation of 11.47 for females ($p < .05$).

Females had higher AE-RO scores with a mean of 6.38 and a standard deviation of 11.84 as compared to males with a mean of 5.56 and standard deviation of 11.44 ($p < .05$). Although statistically significant differences were noted by Kolb and Kolb (2005), they caution against generalizations as there was considerable overlap between the male and female distributions on both AC-CE and AE-RO scores.

Yeung et al. (2006) studied first year students taking Chemistry at the University of Sydney, Australia. Their work showed that females show a higher degree of feeling characteristics than males, while males are more predominant in thinking characteristics. They also noted that students with higher thinking characteristics performed better than those with higher feeling characteristics on their end of term exams. However, the preferred mode of instruction and assessment in university (lecture, individual guided labs, and written examinations) caters to the thinking characteristics. A study by Loo (2004) showed that men preferred doing practical exercises more than women, while women preferred more collaborative activities such as group work and peer assisted help sessions. This implies that males favour Kolb's Active Experimentation while females prefer Kolb's Reflective Observation. However, Smedley's (1987) study of 441 chemists, who were part of the American Chemical Society, showed no significant differences in learning style by sex.

Research by Philbin, Meier, Huffman and Bouverie (1995) found that, in a sample of adults of varying age, 48% of males preferred the assimilator learning style, while only 20% of women did. The women's styles were more varied and primarily Diverging and Converging. This study would indicate that women would likely respond better to faculty who acted in the role of a motivator or coach, while males would in general, respond better when faculty acted in the role of expert.

**Limitations of the Kolb Learning Styles Inventory and Validity**

Kolb (1984) points out the greatest limitation of the instrument: the results are based on the way the learners rate themselves. Although no learning style is considered better or worse in helping students to succeed academically, the individual completing the questionnaire might perceive there to be preferential choices. As well, the Kolb LSI only gives relative strengths within the learner, not compared to other learners. Garner (2000) believes that simplifying learning styles to only four categories is too few. Concerns regarding low test-retest reliability in the literature led Coker (2000) to suggest that reliability might be low due to the respondents thinking of one learning situation during the administration of the first test and a very different learning situation during the retest. Kolb (1976) stated that the individual's interpretation of the learning context would influence test-retest reliability. Kolb argues that test-retest reliability is not an appropriate measure, as learning styles are not fixed but flexible. If a person were to think of two very different learning experiences during the separate occasions of the test and the retest, then it would be expected that the results would be quite different.

To increase test-retest reliability, Coker and Pedersen (2004) studied whether more specific instructions given on each of the test and retest situations resulted in higher reliability. Coker and Pedersen (2004) studied two groups of university students who were randomly assigned to either receive more general instructions or more specific instructions regarding thinking of a learning task. The test-retest reliability of all four of the inventory scales, CE, RO, AC, and AE, were assessed with Pearson product-moment correlations for the two separate groups for the test and the retest, which were at the beginning and end of the semester, an approximately three month interval. In each case, reliability estimates improved when the participants were given a specific learning task to consider during the test and the retest. These increases were: CE ($r$ =.20 to .40); RO ($r$ = .40 to .51); AC ($r$ = .35 to .45); and AE ($r$ = .10 to .39). Internal consistency (coefficient alpha) also increased with the more specific instructions given to participants: CE (α= .34 to .57); RO (α= .57 to .67); AC (α= .52 to .62); and AE (α= .18 to .56). Although the reliability measures remained low, this work by Coker and Pedersen (2004) supports providing more specific instructions regarding a learning task to increase test-retest reliability.

Kolb argues that split-half reliability is the more appropriate measure of reliability. Research shows that LSI scores show a moderately high split-half reliability with coefficients ranging from 0.73 to 0.88 (Kolb, 1984). Over time, the LSI has gained respect as a tool to understand individual development and the learning process (Kolb et al., 2000).

**Justification of the Use of the Kolb Learning Styles Inventory**

The evidence in support of, and against the LSI, was summarized by Mainemelis, Boyatzis and Kolb (2002) who referenced two unpublished doctoral dissertations in the United States. The first dissertation, by Hickox, found that when 81 studies using Kolb's ELT were analyzed, "overall 61.7 per cent of the studies supported the Experiential Learning Theory (ELT), 16.1 per cent showed mixed support" (p.12). The second dissertation, by Iliff, determined that of 101 quantitative studies, "49 studies showed strong support for the LSI, 40 showed mixed support and 12 studies showed no support" (p. 12).

Although Loo (1999) recognizes the weaknesses of the instrument, he argues for its usefulness as a pedagogical tool. Although there are many different learning style models in the literature, the Kolb Learning Styles Inventory was chosen for this research because it has gained respect as a useful tool for students to understand their own learning style, does not require a great deal of time to administer, and has been previously employed in the study of chemists' learning styles (Smedley, 1987 and Towns, 2001).

## First Generation Students

### Definition of First Generation Students (FGS)

The term First Generation Student (FGS) originated in the United States as an eligibility criterion for federal outreach programs, and has been in use for over 20 years (Auclair et al., 2008). However, there is a lack of one clear definition of FGS both across countries and within countries.

In the United States, FGS are defined by the U.S. Department of Education (1998) as students whose parents and/or guardians have not attended a post-secondary institution, while the USA Government's Educational Opportunities Program (Collier & Morgan, 2005) defines FGS as those "with neither parent having completed a four-year college degree in the USA by the time that students entered college". There is a lack of consistency as to whether a student whose parent(s) completed some post-secondary education would be classified as First Generation. Also, the definitions are not clear as to whether the country where the parents completed their studies matters in the definition. In Canada, the definition of a FGS is currently "a student whose parents have not participated in post-secondary studies" (Ministry of Training, Colleges and Universities website, 2011). According to Auclair et al. (2008) the majority of journal articles define a FGS as someone who comes from a family where neither parent attended post-secondary studies. In those cases where parents have different levels of education, the maximum education level of either parent is the determining factor in how the student is categorized (U. S. Department of Education, 1998). A summary of FGS and Non-First Generation Student (NFGS) definitions is shown in Figure 12.

<table>
<tr><th colspan="2">FGS Definition</th><th colspan="4">Non-FGS Definition</th></tr>
<tr><td colspan="2" rowspan="6">Neither parent attended a post-secondary institution (strict definition) / parents have a high school diploma or less</td><td colspan="4"></td></tr>
<tr><td colspan="4">One parent or more with post-seeondary experience<br>Second Generation<br>Continuing-generation student</td></tr>
<tr><td colspan="4">One parent or more with a college degree</td></tr>
<tr><td colspan="2">With college: one parent or more who attended college</td><td colspan="2">With degree: one parent or more with a college degree</td></tr>
<tr><td colspan="2">Moderate: one parent or more who attended college, and at least one parent with a degree (or higher)</td><td colspan="2">High: two parents with a college degree (or higher)</td></tr>
<tr><td>With college: one parent or more attended college</td><td colspan="2">With degree: one parent or more obtained a college degree</td><td>With graduate school: one parent or more obtained a master's degree or doctorate</td></tr>
<tr><td>One parent or more with a junior high school diploma</td><td>One parent or more with a high school diploma</td><td>One parent or more with a community college diploma</td><td colspan="2">One parent or more with a university degree</td><td>One parent or more with a graduate degree</td></tr>
<tr><td>Two parents with a high school diploma or less</td><td>At least one parent attended a post-secondary institution but did not obtain a degree</td><td>One parent obtained a college degree</td><td colspan="3">Two parents obtained a college degree</td></tr>
<tr><td colspan="2">Neither parent obtained a degree (administrative definition)</td><td colspan="4">One parent or more with a college degree<br>Seeond generation<br>Continuing-generation student</td></tr>
<tr><td colspan="2">Neither parents nor siblings attended college for more than a year</td><td colspan="4">Second generation: one parent or more who attended college for more than a year</td></tr>
</table>

Figure 12. Summary of definitions of First Generation and Non-First Generation students in the literature. Adapted from Auclair et al., 2008 with permission. Copyright 2008, National Library of Canada Cataloguing in Publication.

At the time this work was completed, First Generation Students were defined at Brock University as those who were the first in their family to attend university. Since then, the working definition at Brock University has been revised such that those who had siblings attend university are still considered First Generation. For the purposes of this research, the term First in the Family Students (FFS) will refer to those students whose parents have not attended university (FGS) and who are also the first in their immediate family to attend university. Non-First in the Family (NFFS) will include those FGS who are not the first in their immediate family to attend university as they had at least one sibling attend university. However, most previous research in this field studies FGS rather than FFS.

## Enrollment and Retention of First Generation Students

Kamanzi et al. (2010) report that a student's likelihood of going to university in Canada was strongly associated with parental education level. In 2005, 29% of FGS (defined as those who do not have at least one parent who holds a post-secondary degree) attended university, as compared to 69% of NFGS (those students who have at least one parent who does hold a post-secondary degree). This proportion of FGS students is approximately equal in all Canadian provinces. Auclair et al. (2008) report that the percentage of FGS (those whose parents have no experience with post-secondary education) who enroll in four year post-secondary education is 27%, compared with 42% of those whose parents have some post-secondary study, and 71% of students who have at least one parent who completed a degree. Kamanzi et al. (2010) did not find a difference with respect to the percentage of FGS who completed their degree compared to NFGS where FGS are defined as those who do not have at least one parent who completed a post-secondary degree while NFGS are those who have at least one parent who did complete a post-secondary degree. However, they did find that FGS are significantly less likely to continue onto graduate studies.

According to Conrad, Canetto, MacPhee, and Farro (2009) and the work by Kamanzi et al. (2010), FGS (defined as those who do not have at least one parent who completed post-secondary) have lower rates of enrollment and retention than NFGS (those who have at least one parent who did complete post-secondary) in the physical sciences and engineering programs in both the United States and Canada. Many FGS science students have in effect, two strikes against them. The average for FGS students is often significantly lower than for NFGS. As well, the Faculty of Mathematics and Science at Brock University has one of the highest percentages of students on academic probation after first year.

Kamanzi et al. (2003) state that FGS suffer from several disadvantages compared to their NFG peers, including lower academic preparedness, less academic cultural capital, lower levels of financial and emotional support from family and friends, and difficulties with social and academic integration. FGS report less encouragement from family and friends, and in fact may receive resistance to their attending post-secondary education since it represents a departure from family traditions. FGS (defined as those who come from families where neither parent had more than a high-school education) are also less likely to perceive their instructors as being concerned with their success (Pascarella, Pierson, Wolniak & Terenzini, 2004).

In one of very few Canadian studies on the experiences of FGS (those students, neither of whose parent had attended post-secondary education), Grayson (1997) studied 1849 students at York University in Toronto, Ontario, Canada, and found that FGS scored lower in terms of grade point average in their first year of studies (5.37 for FGS and 5.70 for NFGS with 9.00 being a maximum score). An analysis of variance indicated that the "differences are significant at the 0.000 level" (Grayson, 1997, p. 664). According to Horn (1998), almost one-quarter (23%) of FGS (defined as those who have both parents who have a high school education or less) who begin four-year college programs in the United States do not return for their second year, as compared to 10% for NFGS. The U.S. National Council for Educational Statistics (1998) and the National Center for Education Statistics (2005) found that FGS are less likely to complete any degree, controlling for age, ethnicity, and socioeconomic status. Ishitani (2006) also found that FGS (defined as those students who had neither parent graduate from college or university) were 71% more likely to leave post-secondary education than NFGS, when controlling for race, gender, high school grade point average, and family income, especially in the first year of study. This research also noted that FGS were less likely to complete their four-year programs in a timely manner as compared to NFGS.

## Academic Success for Subcategories of First Generation Students

Different researchers often subcategorize students depending on whether a parent has at least some post-secondary education, but did not obtain a diploma or degree. It is thought that if a parent has some experience with the post-secondary system, they will be able to better advise their children than those with no previous experience. The percentage of students still enrolled by year (survival rate) was studied by Ishitani (2006) in order to understand the short-term and long-term effects of parental education levels. Their results are shown in Figure 13.

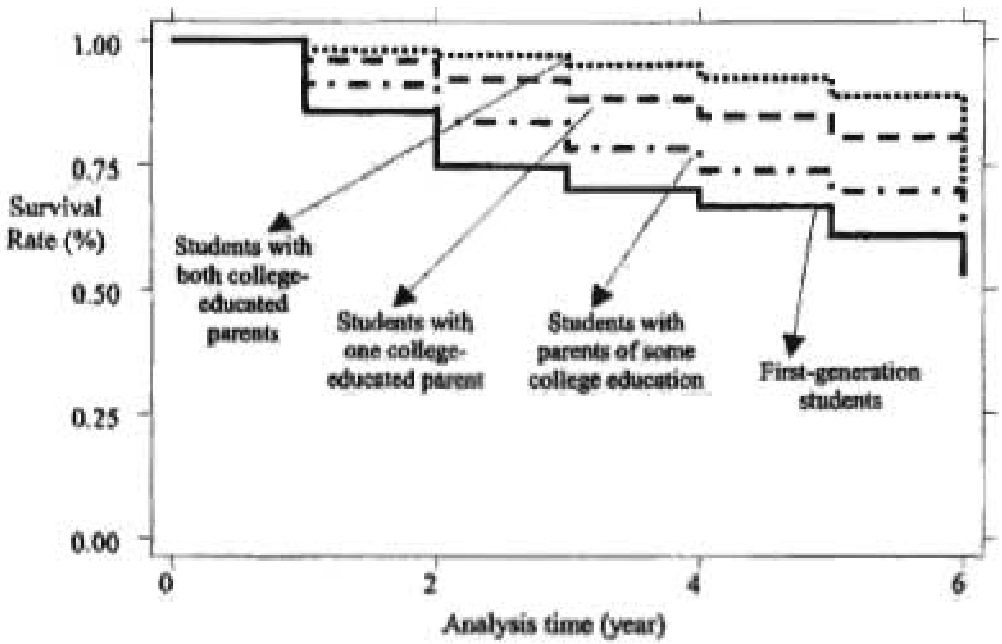


Figure 13. Survival rate in post-secondary education by parental educational background. Reprinted from Ishitani, 2006 with permission. Copyright 2006, The Journal of Higher Education.

FGS (those students who had neither parent attend college or university) were more likely to leave post-secondary studies prematurely than their NFG colleagues, and also more likely to leave prematurely than those students whose parents had completed some post-secondary education. This study defined attrition (non-survival) as leaving their initially enrolled institutions and not returning. It did not track whether students transferred to another institution. This definition included both voluntary withdrawal and academic dismissal. For each year of study, FGS were at higher risk of withdrawing from post-secondary study as compared to NFGS. FGS were 8.5 times more likely to drop out as compared to those students whose parents both completed post-secondary education, while students whose parents had some post-secondary education were 4.4 times more likely to drop out than those whose parent(s) completed their diplomas or degrees (Ishitani, 2006, p. 873). FGS were also less likely to complete their studies in a timely manner; FGS were 51% less likely to complete in their fourth year, as compared to those students whose parents had graduated from post-secondary. Students whose parents had some post-secondary experiences were 44% less likely to complete their studies in the fourth year (Ishitani, 2006). The influence of First Generation status on a student's academic success gets weaker as students progress through their post-secondary education. FGS who stay in post-secondary study catch up to NFGS and compensate for their initial lower cultural capital, suggesting a resilience effect. However, this effect may also apply only to those who persist, since a high percentage of FGS (defined as those whose parents had no experience with post-secondary education) do not complete their degrees (Auclair et al., 2008).

**Adaptation to the Academic Culture by FGS and NFGS**

Choy (2001) and Nuniz and Cuccaro-Alamin (1998) both found that one of the key predictors of persistence in post-secondary education was the level of education their parents achieved. Nunez and Cuccaro-Alamin (1998) hypothesize that NFGS have a clear advantage over FGS (defined as those whose parents never participated in post-secondary education) since NFGS have their parents to assist them in adapting to the role of a college or university student. Prospero and Vohra-Gupta (2007) determined that one of the primary reasons for FGS not being as successful as NFGS was a lack of "academic integration" which includes good study habits by the student, meaningful faculty-student contact outside of the classroom, knowledge of and access to academic support services, and effective academic advising services. Kim and Sax (2009) claim that interactions with faculty in lecture, in lab, during office hours, or through e-mail, are key components of student development in college. Their research showed that NFGS are more likely than FGS to work with faculty on research projects for course credit, communicate with faculty by e-mail and in person, and interact with faculty during lecture.

Elkins et al. (2000) showed that academic integration and social integration are the best predictors of FGS (those with parents with no post-secondary education experience) retention rates. While both FGS (students whose parents have not attended a post-secondary institution) and NFGS face new challenges and integration into the post-secondary environment, NFGS have a definite advantage in terms of knowledge regarding the university culture (U.S. Department of Education, 1998). Prospero and Vohra-Gupta (2007) report that "the goal of academic integration for first-generation students may be a crucial aspect of academic achievement" (p. 972) and academic integration was determined to have the highest positive contribution to academic achievement among all variables analyzed. In the work of Prospero and Vohra-Gupta (2007), a FGS is defined as one whose parents did not complete a college degree program.

FGS are essentially trying to master more information than NFGS. While both groups must learn their course material, FGS are also trying to understand what it means to be a college or university student. According to Collier and Morgan (2008), it is easier for NFGS to take on the role of the college student due to greater familiarity with the concept from their parents, while FGS do not have parents who can help them to understand the university's expectations. In fact, Hsaio (1992) notes that often parents, siblings, and friends who have no experience with post-secondary education may not only be unsupportive, but negative in their attitudes. There is a lack of research into how siblings' experiences of attending post-secondary education affect academic achievements of younger FGS (defined as a student whose parents have not participated in post-secondary education). Adelman (1999) cites the importance of determining how academically successful FGS succeeded despite their increased challenges in order to increase the likelihood of success for FGS.

Collier and Morgan (2008) determined that FGS (those with neither parent having completed a four-year college degree in the USA by the time that students entered college) had much more difficulty in understanding the expectations of faculty, and wanted more detail than NFGS in their syllabus, how to take notes, requirements of assignments, and specifics about tests and exams. Fallon (1997) discussed the role that role models (parents and siblings) have in transmitting relevant knowledge of the values, language, regulations, and expectations, that students need in order to navigate post-secondary studies successfully.

The findings of Ernest Pascarella, Professor of Education, University of Illinois at Chicago, who studied approximately 3000 students, showed that FGS (those who come from families where neither parent had more than a high-school education) reported a great deal of frustration with the mechanical aspects of their written work such as spelling, grammar, and how to format papers. FGS also reported more issues with time management. He notes that FGS are often less skilled in reading, math, and critical thinking at the beginning of their college careers and showed less improvement in those skills than NFGS during their first year (Pascarella et al., 2004).

## Adaptation to the Social Culture of Post-Secondary Education: Living Arrangements and Employment of FGS

FGS (those whose parents have not attended a post-secondary institution) are less likely to live on-campus and often cite being able to live at home and be employed while attending school as very important reasons for selecting their institutions (U.S. Department of Education, 1998). As the level of parental education increased from high school, to some college education, to a degree, so did the likelihood of living on campus (U.S. Department of Education, 1998). Since both living at home and being able to work are important to FGS, this suggests that FGS are operating under tighter financial constraints than NFGS. According to a study by King (2002), students who worked 14 or more hours per week were much more likely to drop out of post-secondary education than those who worked less or not at all. A lack of social integration due to not living on campus and requiring to be employed many hours in addition to academic responsibilities could lead to feelings of isolation, and increased drop-out rates.

## Academic Goals of FGS vs. NFGS and Cultural Capital of their Parents

Cultural capital refers to non-financial social assets such as education, experience, or intellect which would be valuable to improve social mobility. Parents who attended university are more aware of the importance of study and attaining higher degrees while parents of FGS do not understand the academic culture and the value of higher degrees. Even when parents of FGS are supportive of their pursuit of higher education, they often can offer little in the way of assistance or advice. Parents of NFGS might be able assist their children with their studies, but even if they are not able to do so, they are able to advise their children regarding what sources of help are available and educate their children on the culture of academia. For example, parents of NFGS might encourage their children more strongly to speak with their professors than parents of FGS who do not understand that professors hold office hours specifically to answer student questions. According to Auclair et al. (2008), researchers have found significant differences between FGS and NFGS in terms of the highest degree they hope to attain. The fact that the expectations of FGS were significantly lower than those of NFGS, is thought to be the result of the difference in cultural capital between parents of FGS and NFGS.

**Academic Contacts with Faculty, Peers, and in Academic Skills Workshops**

Grayson (1997) determined that participation in academic contacts with faculty and peers outside of class increases the GPA of FGS and narrows the gap between the academic achievement of FGS and NFGS. However, FGS are less likely to participate in extracurricular campus activities, and report difficulty adjusting to post-secondary education as well as feelings of isolation (Prospero & Vohra-Gupta, 2007).

Kamanzi et al. (2003) state that the presence of a role model, such as a faculty member or upper year peer, can increase the likelihood of enrollment and academic success through social and cultural capital as well as assistance with academic integration. Tinto (2000) determined that when campuses linked first-year students with faculty beyond the impersonal lecture classes, they experienced a higher percentage of first-year students continuing on in their studies.

According to the U.S. National Survey of Student Engagement (2006), students who participate in collaborative learning programs and interact with faculty are more likely to get better grades, are happier with their education, and are more likely to stay in college. Such programs, while beneficial to all students, would be particularly valuable to FGS to increase their academic integration to post-secondary studies. Engagement in the university for FGS improves their grades, and decreases the gap in achievement between themselves and their NFG peers. Application of these methods will thereby increase the likelihood of success for both FGS and NFGS.

## The Chemistry Attitudes and Experiences Questionnaire (CAEQ)

### Development of the CAEQ

Coll, Dalgety, and Salter (2003) believe that introductory Chemistry courses have two primary purposes: "to teach the basic concepts students need to undertake further education in chemistry (and other science-related disciplines) and to engender a positive attitude toward chemistry" (p. 649). However, data regarding abstract concepts such as attitudes are often obtained qualitatively, as they are difficult to quantify. Qualitative data obtained by interviews does allow the participant to elaborate on their answers, but data analysis is often more difficult.

Two of the most widely used instruments to measure attitudes in the sciences are the Scientific Attitudes Inventory II (SAI II) (Moore & Goy, 1997) and the Test of Science Related Attitudes (TOSRA) (Fraser, 1978). These tests were deemed inadequate for the study of university students since the SAI II lacks validity (Munby, 1997) and the TORSA is designed for high-school students. Coll, Dalgety, and Salter (2002) designed the Chemistry Attitudes and Experiences Questionnaire (CAEQ) to quantitatively measure a student's attitudes, self-efficacy, and experiences regarding Chemistry at the post-secondary level.

The CAEQ measures students' attitudes towards chemists, Chemistry research, Chemistry as a career choice, and their leisure interest in Chemistry. In addition, the CAEQ measures self-efficacy with respect to students' confidence in lab, using formulas, writing about Chemistry, discussing Chemistry with their peers or a scientist, and thinking critically about Chemistry. The CAEQ also measures students' opinions of their experiences in lecture, lab, and tutorials. A copy of the CAEQ used in this research is provided in Appendix E.

**Definitions of Key Terms**

In order to develop a framework for the CAEQ, the authors first had to define terms such as Chemistry, attitude towards Chemistry, and Chemistry self-efficacy. Chemistry is defined by Coll, Dalgety, and Salter (2002) as "the learned patterns for thinking, feeling and acting that are transmitted via the acquisition of chemistry theory, skills and values" (p. 22). They chose Allport's definition of attitude, which was "a mental and neural state of readiness, organised through experience, exerting a directive and dynamic influence upon the individuals' response to all objects and situations with which it is related" (Horowitz & Bordens, 1995, p. 228). The definition of self-efficacy was Bandura's (1985) definition as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performance" (p. 391). Coll, Dalgety, and Salter (2002) define a "student's self-efficacy being his or her perception of their ability to undertake a specific scientific task or tasks" (p. 20) and considered any experience resulting in a belief formation about Chemistry (attitudinal, knowledge or skill based) to be a learning experience.

**Theoretical Background of the CAEQ**

The CAEQ is based on the Theory of Planned Behaviour (TPB) which maintains that behaviours are determined by many influences (Coll, Dalgety & Salter, 2002). The CAEQ is based on the antecedents of the attitude towards enrolling in Chemistry, namely their learning experiences, attitudes towards Chemistry, and their Chemistry self-efficacy, as shown in Figure 14.

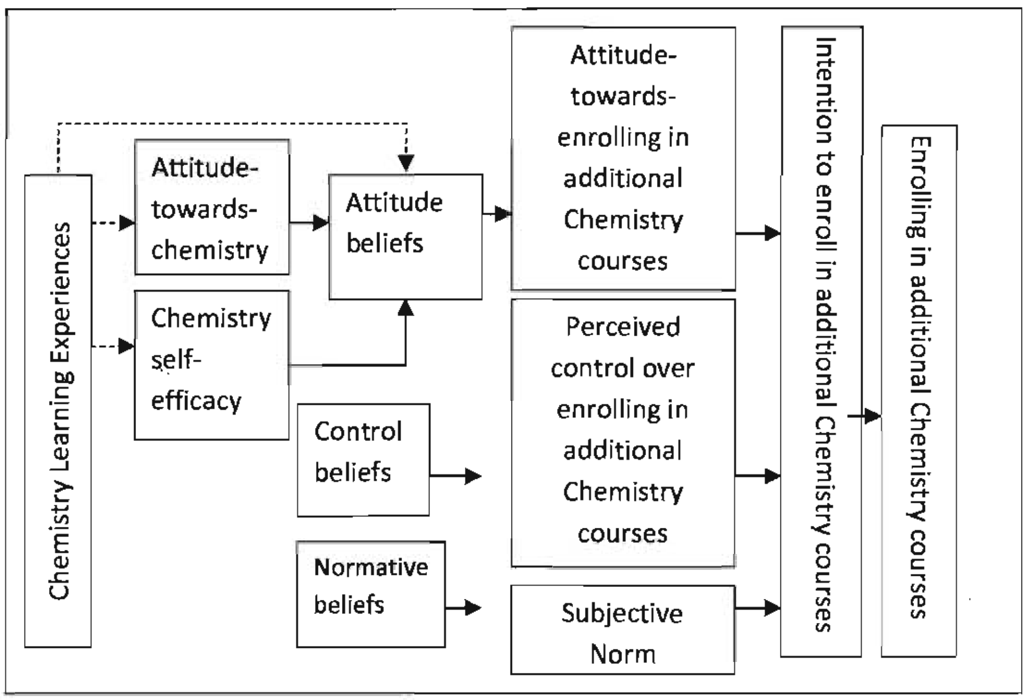


Figure 14. The modified theory of planned behaviour based on Ajzen, 1989. Adapted from Dalgety and Coll, 2006b with permission. Copyright 2006, Higher Education.

The students' attitudes towards Chemistry and their Chemistry self-efficacy will combine to form their attitude beliefs, which will lead to their attitude towards enrolling in further Chemistry courses. How much control they perceive to have over enrolling in additional Chemistry courses (required or elective) is based on their control beliefs. Their subjective norm is based on the students' normative beliefs; the students' beliefs are influenced by the beliefs of others such as teachers, family, and the media. These factors could combine to result in the students' intention to enroll in additional Chemistry courses, which could lead to the behaviour of enrolling in additional Chemistry courses.

## Self-Efficacy

University professors often state that the main factors influencing achievement in courses are attitude and motivation (Haladyna et al., 1982). The self-efficacy of students in the sciences has been studied much less than the self-efficacy of students in mathematics (Coll, Dalgety & Salter, 2002) and requires to be studied specifically for each subject. Dalgety and Coll (2006b) report that a lack of interest and perceived lack of ability in science are reported as obstacles to taking or continuing in science courses. They state that an apparent decrease in Chemistry self-efficacy causes some students to drop Chemistry courses in university. Self-efficacy is thought to be a better indicator of likelihood of continuing in Chemistry since achievement is subjective, and students will measure academic success in their courses differently. One student might consider 70% to be a low grade, and have low self-efficacy, while another might perceive it to be a good grade, and have high self-efficacy. Work by Yucel (2007) showed that students' attitudes were positively correlated with their course grades in Chemistry. Self-efficacy is also influenced by each student's attitude towards science (Dalgety & Coll, 2006a).

Males report higher self-efficacy than females in the physical sciences, while females report higher self-efficacy than males in the natural and life sciences (Andre et al., 1999). Specifically, males report higher self-efficacy in skills such as explaining concepts to other students, proposing research questions that can be answered experimentally and applying theories and choosing the correct formula to solve a problem. Males tend to identify specific areas of chemistry where they are less confident, whereas females tend to have lower self-confidence overall. This could partially explain the under-representation of females in science. While males are more likely to identify specific tasks to improve, females tend to see their lack of ability more globally, and lacking specific skills to improve, often choose not to continue in this field. Experiences in first year chemistry affect females significantly, especially if their experiences are negative (Dalgety & Coll, 2006a). Dalgety and Coll (2006a) state that students with high self-efficacy often attribute their academic success to effort as well as ability, and are more likely to persist in science.

## Attitudes and Normative Beliefs

Dalgety and Coll (2004) reported that most students that they surveyed had at least one mentor who thought of chemists in a relatively positive manner, as intelligent, hard-working and analytical people who consider ethical behaviour in science as part of their own personality, and that of others in scientific professions. Students reported their belief that the media was strongly anti-Chemistry, and indeed anti-science generally. Spending time with a scientist or member of the science industry is likely to have given the student an increased awareness about Chemistry and support for Chemistry learning that other students not associated with a scientist do not receive.

## Research Findings using the CAEQ

Dalgety and Coll (2006b) found that students reported positive experiences in lecture, lab, and tutorials. The highest scores corresponded to non-traditional lectures, material that related theory to real-world experiences, and teaching that re-enforced the students' perceptions of their ability to do well in their chemistry courses. Dalgety, Coll, and Jones (2003) encourage the use of real-world examples both in laboratory and lecture classes and the improved use of visual aids to engage students in the learning. Their research showed that students who were interested in the field and reported positive learning experiences continued into second year, even if they found the material difficult.

## Limitations of the CAEQ

Data obtained from the CAEQ are ordinal in nature. There is not a continuous seale, but rather individuals must select one of five or seven possibilities depending on the scale. Therefore, to report the data, the correct measure is in question. Strictly speaking, the median is more appropriate since means are used for interval data. While some authors report the central tendency as the median, others report the estimated mean. The latter approach is more common (Coll, Dalgety & Salter, 2002). Since one is dealing with ordinal data where a score of zero is not an indication of the complete absence of the measured item, ratios can only show direction of the difference, but not the magnitude of the difference. One measure that is twice the value of a mean of another measure cannot be deemed to be twice as important. Rather, all one can report is that the first measure is deemed to be more important than the one with the lower estimated mean.

## Validity of the CAEQ

Dalgety, Coll, and Jones (2003) established face validity of the CAEQ through the use of a panel of experts (Chemistry faculty and graduate students) and a sample of undergraduate students representative of the intended population of those who would complete the CAEQ. The experts provided their views on scales, subscales, and individual items, as well as their recommendations for which items to include in the instrument. Undergraduate students, representative of the intended population who would complete the CAEQ, provided input into the clarity and readability of items through interviews. As well, an expert in the teaching of English as a Subsequent Language (ESL) students approved the readability of the instrument for ESL students.

The CAEQ's concurrent validity was confirmed through comparisons of Chemistry majors and non-majors. Chemistry majors had a more positive attitude about Chemistry, possessed higher self-efficacy, and reported more positive learning experiences than non-majors in Chemistry. Differences across subscales for administrations both at the beginning of the academic term (n=332) as well as the end of the academic term (n=337) were statistically significant ($p<0.05$) (Dalgety, Coll, & Jones, 2003).

The CAEQ's predictive validity was studied through correlations of the mean response for the learning experiences subscales with the attitude and self-efficacy subscales using the Pearson correlation coefficient. Dalgety, Coll, and Jones (2003) found all correlations to be statistically significant ($p<0.01$). Since the learning experiences subscales are influenced by the attitudes subscales as well as the self-efficacy subscale and vice versa, the CAEQ has high predictive validity. It predicts the results that it was designed to.

The reliability of the CAEQ subscales was studied using Cronbach alpha and resulted in an average reliability of 0.74 at the start of the year (n= 332) and 0.84 (n=337) at the end of the year. This makes the CEAQ comparable with TORSA (0.82; n= 324-340) (Dalgety, Coll & Jones, 2003). The CAEQ is believed to be a valuable instrument for educators to understand the attitudes, experiences, and self-efficacy of their students.

## Goals of this Research Project

The goal of this research project was to identify the factors which correlate to academic success in students taking first and second year chemistry courses at Brock University. A multi-year study was conducted from Winter 2008 to Fall 2009 with participants from CHEM 1P00 (Introductory Chemistry), CHEM 1F92 (General Chemistry), CHEM 2P20 (Organic Chemistry), and CHEM 2P42 (Analytical Chemistry) completing a series of questionnaires and providing consent to obtain their final grades in Chemistry courses. The purpose of this research project was to study first and second year Chemistry students to determine if correlations exist between academic achievement, as measured by final grade, and the following factors: learning styles (determined by a modified version of Kolb's Learning Styles Inventory), chemistry attitudes, experiences, and self-efficacy, as measured by Dalgety, Coll and Jones' Chemistry Attitudes and Experiences Questionnaire (CAEQ), and demographic factors such as sex and parental educational background.

## Methods and Materials

### Participants

Brock University students taking CHEM 1P00 (Introductory Chemistry), CHEM 1F92 (General Chemistry), CHEM 2P20 (Organic Chemistry), and CHEM 2P42 (Analytical Chemistry) were invited to participate in this research project, which received Research Ethics Board Approval (REB 07-264). The CHEM 1P00 class was the first group asked to participate in the Winter 2008 Term. The CHEM 1F92 class was invited to participate in the Fall/Winter 2008-2009 academic year. The second year CHEM 2P20 classes were invited to participate in the Spring 2008 term, the Spring 2009 term, and in the Fall 2009-2010 term. The CHEM 2P42 class was invited to participate in the Fall 2009-2010 academic term.

### Description of Courses

#### Chemistry 1P00

Chemistry 1P00 is an Introductory Chemistry course taken by students who either did not take grade 12 chemistry in high school, did not achieve over 70% in their grade 12 course, or who are mature students and took chemistry years ago. It is a half-credit course offered in the Winter term consisting of three one-hour lectures for 12 weeks, and 1.5 hours of lab and 1.5 hours of tutorial weekly. Generally, approximately 100 students enroll in this course each year. The questionnaires were administered to this class on their final day of lecture following a review for the final exam.

**Chemistry 1F92**

Chemistry 1F92 (Chemical Principles and Properties) is the general chemistry course taken by Chemistry majors and non-majors. The prerequisites for CHEM 1F92 are either Grade 12 Chemistry with a final grade of 70% or higher; successful completion of CHEM 1P00, or permission from the Chemistry department. CHEM 1F92 is a full-credit course and runs in Fall-Winter for 24 weeks. Lectures are one hour in duration three times a week, while labs are three hours in duration with five labs per term. Although tutorials are now part of CHEM 1F92, they had not yet been included in the curriculum in 2008-09 when the questionnaires were completed. Approximately 400 students register for CHEM 1F92 each year. Data were collected over a period of two weeks in 16 different lab sections.

**Chemistry 2P20**

Chemistry 2P20 (Organic Chemistry) is offered in the Fall and Spring terms. The prerequisite is either 60% or higher in CHEM 1F92 or a comparable course at another university, or permission of the instructor. The Fall course is 12 weeks long with three one-hour lectures per week, ten labs (one each week), and a one-hour tutorial each week. The course is condensed to four weeks in the Spring Term, with the same number of labs and tutorials as in the Fall term. Typically, approximately 200 students enroll in CHEM 2P20 in the Fall term and approximately 40 in the Spring term. Enrollment is quite high in CHEM 2P20 as this is a required course for not only Chemistry majors, but also Biology majors with aspirations of attending medical school.

**Chemistry 2P42**

Chemistry 2P42 (Analytical Chemistry) is a half-credit course offered in the Fall Term. The prerequisite is either 60% or higher in CHEM 1F92 or a comparable course at another university, or permission of the instructor. The course consists of three one-hour lectures each week for twelve weeks, and ten weeks of three-hour labs. Tutorials are not part of this course. The enrollment in this course is typically approximately 40 students.

## Completion of Questionnaires

Students were asked to complete the questionnaires either during lecture, labs, or tutorials depending on when the instructors and/or senior lab demonstrators of the courses could allocate time. Students were not notified in advance that they would be asked to participate. In all cases, the Primary Student Investigator followed a script (Appendix A), which was part of the proposal presented to the Research Ethics Board. This script explained the project to the students, what their participation would involve, and emphasized that participation was voluntary and that they could choose to participate or not without any consequences. The Primary Student Investigator was available to answer any questions while students completed the questionnaires. Students were generally given 30-40 minutes to complete the questionnaires and were asked to return them to the envelope, regardless of whether they had chosen to complete the surveys or not. Students were also asked to seal their envelopes. If students chose not to complete the questionnaires, they could work on review or tutorial questions, or their lab procedures.

The CHEM 1P00 class was asked to complete the questionnaires at their final Chemistry lecture. Of the 106 students who were still registered on that day, 31 were present on the final day of class, and 29 completed at least part of the questionnaire package correctly and provided written consent to participate in the research project. However, two of these 29 students did not receive a final grade in the course, and therefore data for 27 of the 29 students is presented.

The CHEM 1F92 students were addressed in their individual lab sections during the third lab of the year as the lab procedure involved waiting for 10-15 minutes several times to allow samples to cool. All CHEM 1F92 surveys were completed over the two weeks of labs, and before the first mid-term exam. Of the approximately 400 students who were enrolled at this time, 243 students participated in the research and provided signed consent forms. However, 35 of those students did not complete the course to receive a final grade. Therefore, data correlated to grades was only available for 208 students.

The Spring 2P20 classes were addressed after their final tutorial (Spring 2008) or after their final lecture (Spring 2009). Thirteen of the 17 students present in Spring 2008 completed at least part of the questionnaire package and signed the consent forms, while 15 of the 18 Spring 2009 students present participated. However, one of the students from the Spring 2009 course did not complete the course to achieve a final course grade. As the Spring 2008 and Spring 2009 questionnaires were completed at the end of the term, the exact enrollment at the time when the questionnaires were completed was not known by the Primary Student Investigator. The Fall CHEM 2P20 class was addressed during the first tutorial while the CHEM 2P42 class was asked to complete the questionnaires in the first lab section following safety instruction. Of the 135 students enrolled in the Fall-Winter section of CHEM 2P20, 112 completed the surveys. However 15 did not complete the course to achieve a final grade, and therefore data from students who completed the course was available for 97 students. In CHEM 2P42, all 39 students completed the surveys, however, 15 did not complete the course to receive a final grade, and therefore, course grade data is only available for the 24 students who completed the course.

As some students were enrolled in both CHEM 2P20 and CHEM 2P42 concurrently, these students were asked to complete separate questionnaires for each course. Sixteen students completed two sets of surveys. Although the demographic data and CAEQ attitudes data collected would be the same for these students, the Kolb LSI referred specifically to learning Organic Chemistry when administered to the CHEM 2P20 class, and to learning of Analytical Chemistry when administered to the CHEM 2P42 class. As well, the CAEQ confidence questionnaire asked students about their confidence in each particular course. This would provide information about learning styles in each of the two types of Chemistry courses and the students' confidence in each.

Where students signed the consent forms, but did not complete all surveys correctly, partial data was incorporated into analyses when possible. Incomplete Kolb data could not be included in analyses, as the questionnaire requires to be completed. Incomplete sections of the CAEQ were included if there were only 1 or 2 incomplete questions, and the means were taken of the answered questions. However, if more than two questions were incomplete, the data were not included for analysis. Each individual demographic question could be included regardless of whether other parts of the demographic questionnaire were completed or not.

**The Questionnaire Package**

Questionnaire packages consisted of separate documents in one large envelope. The first document was a Letter of Invitation (Appendix B), which provided background information about the project. This was followed by a Consent Form (Appendix C), which outlined what participation entailed, possible benefits, the lack of risks, confidentiality, anonymity in the results, and voluntary participation with no consequence if the student chose not to participate. Additional copies of the Consent Form were available so that students could sign one copy and keep a copy for themselves.

Three Questionnaires were included in each package. These included a modified Kolb Learning Styles Inventory (Kolb, 1985), a modified Chemical Attitudes and Experiences Questionnaire (Dalgety, Coll & Jones, 2002), and a demographic questionnaire, developed by the Primary Student Investigator with assistance from Brock University Psychology Professor Dr. David DiBattista.

**Modified Kolb Learning Styles Inventory**

The Kolb Learning Styles Inventory (Kolb, 1985) is a refined version of the original 1976 LSI with improved reliability and clarity of language. It was modified in this study to include the term Chemistry (for CHEM 1P00 and CHEM 1F92), Organic Chemistry (for CHEM 2P20), or Analytical Chemistry (for CHEM 2P42) after each introductory statement. A sample questionnaire is included as Appendix D. For example, whereas the original version (Kolb, 1985) includes the statement "I learn best when:" followed by 4 options which the student is to rank order, the modified version states "I learn Chemistry best when:" followed by the same 4 options as the original inventory. This modification was done for all twelve of the introductory statements to stress the learning of Chemistry as opposed to learning in other courses or contexts. To emphasize the difference between the questionnaires in Organic Chemistry and Analytical Chemistry, the introductory statements for both second year surveys were modified to include the field of Chemistry such as "I learn Organic Chemistry best when:" or "I learn Analytical Chemistry best when:" followed by the same 4 options.

**Modified Chemistry Attitudes and Experiences (CAEQ) Questionnaire**

The CAEQ, (Dalgety, Coll, and Jones, 2003) was developed to determine what factors influence student enrollment in Chemistry courses. A sample of the modified version used in this study is included as Appendix E. The second page of the CAEQ asks students to rate their confidence regarding twenty different aspects of the course by asking "Please indicate how confident you feel about" and listing different tasks Chemistry students might be asked to complete. Question 17 asks students to rate their confidence in "achieving a passing grade in a Part Two chemistry course". Since Brock University does not refer to courses as Part Two, this was modified to "achieving a passing grade in a subsequent chemistry course, such as CHEM (1F92 for the 1P00 class, 2P20 for the 1F92 class, 2P21 for the 2P20 class, and 3P42 for the 2P42 class)". As well, the original version of the CAEQ uses Question 1, which asks students how confident they would be "talking to a scientist about chemistry" as their example of how to complete this page of the survey. However, it does not include this statement in the portion for students to complete. The survey begins numbering the other measures of the Confidence survey with number 2 which was interpreted to mean that Question 1 is to be included in the questionnaire. As well, Dalgety, Coll, and Jones (2003) describe the self-efficacy portion of the questionnaire as comprising a total of 20 items after the initial 61 items were subjected to scrutiny by both Chemistry graduate students and faculty. In the modified version, this question is included in the survey for students to answer. As well, since tutorials were not part of the course requirements for 1F92 (at the time), nor for CHEM 2P42, this section of the survey on experiences in tutorials was simply crossed out for those courses. Finally, since the CHEM 1F92, Fall 2009 CHEM 2P20, and CHEM 2P42 classes were given the questionnaires very early in the term, the page of the CAEQ regarding lab, lecture, and tutorial experiences was not included for these groups.

### Demographic Questionnaire

The final questionnaire (Appendix F) was designed to gain demographical data including gender, family educational background, and pressure to succeed. For the purposes of this research, the term First in the Family Students (FFS) will be applied to those students whose parents have not participated in university education and who are first in their family to attend university. Therefore, these students will not only be First Generation Students, but also not have the benefit or knowledge about university from siblings.

## Analysis of Data

As the Primary Student Investigator was a Teaching Assistant for CHEM 1P00, these questionnaires remained unopened until the final grades had been submitted to the Registrar's Office by the course Instructor. For the other courses, the Primary Student Investigator was not affiliated with the courses, and therefore analysis could begin while the course was still in session. In order for questionnaire data to be included in the analysis, signed consent forms were required. Those packages in which questionnaires were completed, but did not include the signed consent form, were excluded from analysis.

**Analysis of the Modified Kolb Learning Styles Inventory Data**

Each student's individual responses to the modified Kolb Learning Styles Inventory were input into Excel. The LSI consists of 12 introductory statements, each with four options to complete the statement. Students were asked to rank order these options from 4 to 1, where 4 indicates which best described how they learn, and 1 was assigned to the option that least described how they learn. These four options correspond to Kolb's (1984) four different stages of learning including Concrete Experiences (CE), Reflective Observation (RO), Abstract Conceptualization (AC), and Active Experimentation (AE). By using the rankings of the four options to each of the twelve introductory phrases, the learning style of each student was determined, according to the method in the User's Guide for the Learning Style Inventory, developed by Smith and Kolb (1998).

The responses from each student were recorded in a table as shown in Table 2, which shows a set of sample data.

Table 2. Assignment of Ranking Values by Question for the Modified Kolb Learning Styles Inventory

| | Ranking | | | |
|---|---|---|---|---|
| Question | Choice A | Choice B | Choice C | Choice D |
| 1 | 1 | 2 | 4 | 3 |
| 2 | 3 | 2 | 1 | 4 |
| 3 | 4 | 3 | 2 | 1 |
| 4 | 1 | 4 | 3 | 2 |
| 5 | 2 | 1 | 3 | 4 |
| 6 | 3 | 4 | 2 | 1 |
| 7 | 4 | 2 | 1 | 3 |
| 8 | 4 | 3 | 2 | 1 |
| 9 | 4 | 2 | 3 | 1 |
| 10 | 1 | 4 | 3 | 2 |
| 11 | 4 | 3 | 1 | 2 |
| 12 | 3 | 2 | 1 | 4 |

The value assigned to each of the four learning dimensions was calculated as shown in Table 3.

Table 3. Calculation of Total Rank Scores for Each Learning Dimension in the Modified Kolb Learning Style Inventory

| Learning Dimension | Calculation of Total Ranks per Learning Style |
|---|---|
| CE (Concrete Experiences) | (Q1 Choice A) + (Q2 Choice C) + (Q3 Choice D) + (Q4 Choice A) + (Q5 Choice A) + (Q6 Choice C) + (Q7 Choice B) + (Q8 Choice D) + (Q9 Choice B) + (Q10 Choice B) + (Q11 Choice A) + (Q12 Choice B) |
| AC (Abstract Concepts) | (Q1 Choice B) + (Q2 Choice B) + (Q3 Choice A) + (Q4 Choice D) + (Q5 Choice C) + (Q6 Choice D) + (Q7 Choice C) + (Q8 Choice B) + (Q9 Choice D) + (Q10 Choice D) + (Q11 Choice C) + (Q12 Choice A) |
| AE (Active Experimentation) | (Q1 Choice C) + (Q2 Choice D) + (Q3 Choice B) + (Q4 Choice B) + (Q5 Choice D) + (Q6 Choice B) + (Q7 Choice D) + (Q8 Choice A) + (Q9 Choice C) + (Q10 Choice C) + (Q11 Choice D) + (Q12 Choice D) |
| RO (Reflective Observation) | (Q1 Choice D) + (Q2 Choice A) + (Q3 Choice C) + (Q4 Choice C) + (Q5 Choice B) + (Q6 Choice A) + (Q7 Choice A) + (Q8 Choice C) + (Q9 Choice A) + (Q10 Choice A) + (Q11 Choice B) + (Q12 Choice C) |

A single data point for each student was then plotted on an X-Y graph, where the X and Y values were calculated using the Total Rank calculations from the table above, using the following formulas:

X value = AE – RO and Y Value = AC – CE.

The graph is divided into 4 quadrants, with each quadrant representing a dominant learning style. In the Kolb LSI graph, positive AE-RO scores are to the left of the y axis, while positive AC-CE scores are below the x axis, as per Kolb (1998). Positive AC-CE and positive AE-RO values correspond to the Converging learning style. Positive AC-CE and negative AE-RO values are classified as the Assimilating learning style. Negative AC-CE and negative AE-RO values are the Diverging learning style, while negative AC-CE and positive AE-RO correspond to the Accommodating learning style. These quadrants are shown in Figure 15.

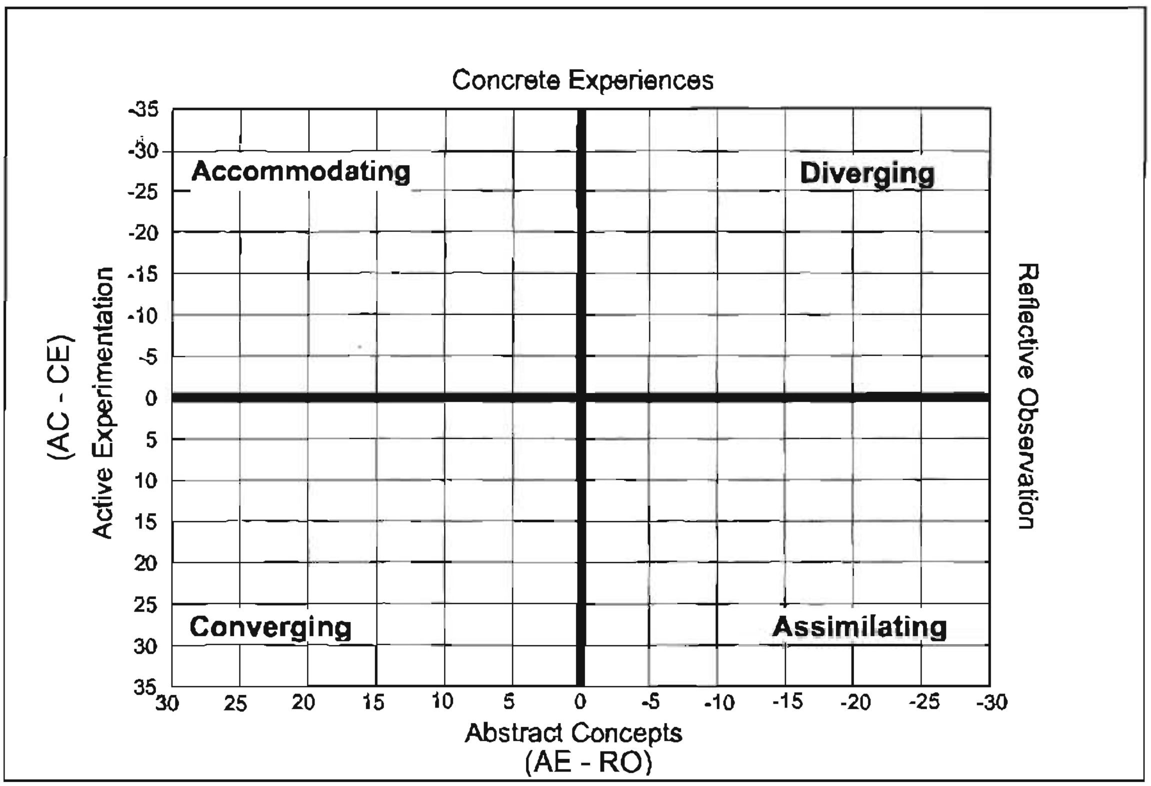


Figure 15. The four learning styles in the Kolb Learning Styles Inventory.

Each student's Kolb Learning Style data point was coded to indicate the grade range achieved by the participant in the Chemistry course. This was done to determine if students of a particular learning style were more academically successful, or if those of a certain learning style were less successful. Learning Style data were also differentiated by sex to determine if differences existed between females and males. Statistical analysis was performed to compare scores on each LSI dimension for males versus females and FFS versus NFFS. Learning style inventories that were incomplete or completed incorrectly were not included in the analysis.

### Centroids

Centroids (the arithmetic mean of the AE-RO and AC-CE values) were calculated for groups of students to show graphically the differences in mean scores for the groups (i.e. males vs. females or FFS vs. NFFS). Centroids were determined by calculating the mean score for the AE-RO values for each group, and the mean score for the AC-CE values for each group, and plotting the mean score as one point (the centroid) for each group.

## Analysis of CAEQ Data

### Analysis of CAEQ Attitudinal Data

Data from the Attitudinal Survey of the CAEQ were entered into Excel. Students were asked to use a Likert scale to indicate their perception of qualities about Chemists, Chemistry research, science documentaries, Chemistry websites, Chemistry jobs, talking to friends about Chemistry, and science fiction movies. There were seven choices including two extreme opposites such as "socially aware" and "socially unaware", and five intermediate rankings. These data were entered into Excel where answers were coded as +3,

+2, +1, 0, -1, -2, or -3. Positive values were assigned to the positive description, with more extreme answers getting higher values. Negative values were assigned to the negative description, with higher absolute value to those nearer the extreme negative description, and neutral rankings were assigned a value of zero. The categories of Chemists, Chemistry research, and Chemistry jobs were analyzed individually with eight, four, and five items respectively. The categories of science documentaries, Chemistry websites, talking to my friends about Chemistry, and science fiction movies were combined since each only had one item, and this category was named Chemistry as a leisure activity.

Means for each category, as well as overall attitudinal scores, were compared with grade achieved in the Chemistry course to determine if any correlations existed. These data were also analyzed for differences by gender and family education background.

**Analysis of CAEQ Confidence Data**

Confidence was rated on a five point Likert scale ranging from totally confident (+2 scoring) to not confident (-2 scoring). Again, neutral answers were scored as zero. Intermediate answers were scored as +1 indicating somewhat confident, and -1 indicating somewhat not confident. The items were grouped according to confidence in various contexts. The groupings were: Confidence in the Laboratory (Questions 2, 3, 4, and 18), Confidence in discussing Chemistry such as tutoring or speaking with scientists (Questions 1, 5, 9 and 20), Critical Thinking (Questions 7, 8, 13, and 17), Confidence in Writing about Chemistry (Questions 12, 15, 16, and 19) and Problem Solving / Using Formulas in Chemistry (Questions 6, 10, 11, and 14). The data were analyzed to determine if correlations existed between confidence and final course grade achieved for the class.

Analyses were done to determine if differences existed between males and females in the five confidence categories or overall confidence, and if differences existed between FFS and NFFS with respect to either overall confidence or on any of the confidence subscales.

**Analysis of CAEQ Experiences Data**

The Experiences portion of the CAEQ asks students to rate how strongly they agree with statements about lectures (10 questions), tutorials (10 questions), and laboratory classes (15 questions). Data were entered into Excel with a scoring of +2 for Strongly Agree, ±1 for Agree, zero for Neither, -1 for Disagree, and -2 for Strongly Disagree. All statements were written such that agreement with the statement indicated that the student felt positively towards the statement. These values were also input into Excel and compared to academic success in the course and analyzed for gender differences.

**Analysis of Demographic Data**

Demographic survey data were input into Excel. Analyses were performed to determine if correlations existed between academic success and factors such as gender, pressure to succeed academically in Chemistry, living arrangements, and family educational background.

**Statistical Analyses**

For all data, appropriate statistical analyses were performed using either Excel or SPSS. Correlation coefficients were classified as having a weak (0.2-0.4), moderate (0.4-0.6), or strong (>0.6) relationship (Cohen, 1988). The t-tests for Pearson r calculations were performed at 95% confidence and independent sample t-tests were performed at 95% confidence. When t-tests determined there was a statistically significant difference between groups, effect sizes were calculated using the "Cohen's d" calculation; the difference between the means was divided by the pooled standard deviation (Cohen, 1988). Effects are classed as small when d= 0.2, medium when d= 0.5, and large when d= 0.8 or greater (Cohen, 1988).

# RESULTS

## CHEM 1P00 Data Collected

One hundred and six students initially enrolled in CHEM 1P00 in Winter 2008, but at the time the questionnaires were completed, 90 students were still registered, and 31 were present at the final lecture. Of those present, 29 completed at least part of the questionnaire package and signed the consent forms. Of those who completed the questionnaires, grades were not available from the Registrar's Office for two of the students, and therefore data from only 27 students was analyzed. For the 27 who completed the course, the mean course grade achieved was 65.59% with a standard deviation of 10.91%. As the small group of students present at the final lecture is very likely not representative of the CHEM 1P00 class, the results for the CHEM 1P00 class must be interpreted with caution.

### Course Achievement for Males and Females in CHEM 1P00

The 19 females in CHEM 1P00 who participated in this research and obtained a final course grade had an average of 65.68% with a standard deviation of 12.40%. The 8 males who participated in this research and obtained a final course grade had an average of 65.38% with a standard deviation of 6.82%. This difference between males and females was not statistically significant ($p= 0.94$).

### Course Achievement in CHEM 1P00 for First in the Family to Attend University Students versus Non-First in the Family to Attend University Students

There was no statistically significant difference between the mean course grade of First in the Family Students (FFS) as compared with Non-First in the Family Students (NFFS) in CHEM 1P00. FFS (n=8) scored a mean of 60.25% with a standard deviation of

10.89% as compared to NFFS (n=19) who had a mean course grade of 67.84% with a standard deviation of 10.38%. This difference (p= 0.10), is not statistically significant.

**CHEM 1P00 Modified Kolb Learning Styles Data**

Of the 29 students who completed questionnaires, two did not receive a final grade in the course, and one student did not complete the modified Kolb Learning Styles Inventory correctly. Therefore, Kolb LSI data are available from 26 students (19 females and 7 males).

The data from the modified Kolb Learning Styles Inventory showed that the students in the CHEM 1P00 class who completed the surveys consisted of only Converger (11 students) and Assimilator learning styles (15 students) as shown in Figure 16.

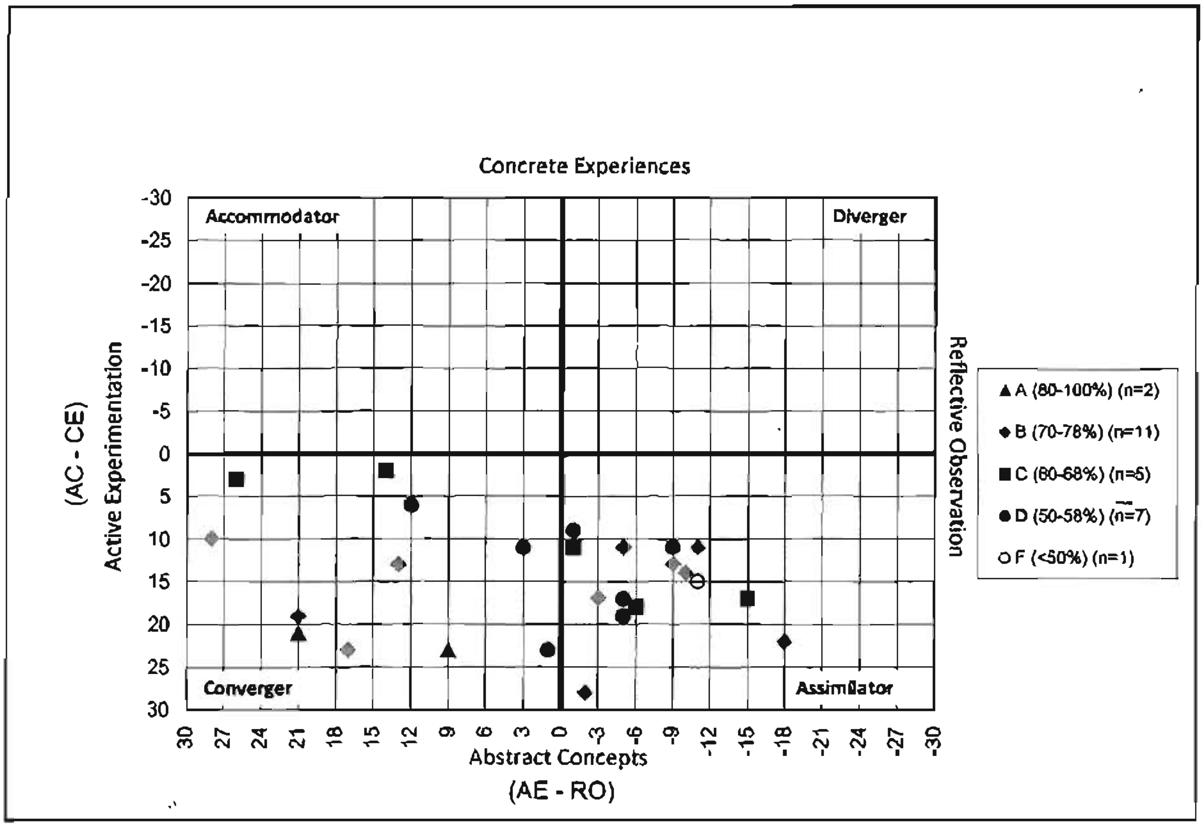


Figure 16. Kolb Learning Styles, coded based on grade achieved in CHEM 1P00.

Table 4 shows the mean scores for each dimension of the Kolb LSI as well as the AE-RO and AC-CE scores. One sample t-tests were performed to determine if the AE-RO and AC-CE scores were significantly different from zero. For AE-RO, $t(25) = 0.81$, $p = 0.43$, and therefore not significantly different from zero. For AC-CE, $t(25) = 11.75$, $p<0.01$, and therefore significantly different from zero. The CHEM 1P00 students have a preferred learning style which favours abstract concepts over concrete experiences, but AE-RO scores do not differ significantly from zero. Therefore, neither AE nor RO is favoured by these students.

Statistically significant positive correlations of AC scores with CHEM 1P00 grade ($r = 0.50$) were found, $t(24)=2.81$, $p=0.01$, while scores of RO were significantly negatively correlated ($r = -0.45$) to the 1P00 grade achieved, $t(24)=-2.49, p=0.02$. All other correlations were not statistically significant.

Table 4. Mean, Standard Deviation, and Correlation to Course Grades for AC, CE, AC-CE, AE, RO, and AE-RO Scores for CHEM 1P00

| CHEM 1P00 | AC | CE | AC-CE | AE | RO | AE-RO |
|---|---|---|---|---|---|---|
| Mean (n=26) | 34.50 | 19.62 | 14.88 | 33.69 | 31.62 | 2.08 |
| Standard Deviation | 5.69 | 3.95 | 6.46 | 6.62 | 8.47 | 13.11 |
| Correlation to Course Grade ( r ) (df=24) | 0.50 | 0.24 | 0.29 | 0.09 | -0.45 | 0.34 |
| t-test for Pearson r t value (df=24) | 2.81 | 1.19 | 1.51 | 0.44 | -2.49 | 1.78 |
| t-test for Pearson r p value (df=24) | 0.01* | 0.25 | 0.14 | 0.66 | 0.02* | 0.09 |

*Note.* *$p< 0.05$

It must be noted that only approximately one-third of students who were enrolled in CHEM 1P00 were present when the questionnaires were administered. While the data show only the Converger and Assimilator learning styles, it is not clear whether there were students in the Accommodator and Diverger learning styles who were simply not present that day, had previously been enrolled in the class but withdrew, or whether students with those learning styles had never been enrolled in this course.

The mean grade in CHEM 1P00 for those in the Converger learning quadrant (n=11) was 68.82% with a standard deviation of 12.32%, while those in the Assimilator learning quadrant (n=15) had a mean of 63.27% and a standard deviation of 9.92%. The difference between the two learning styles was not statistically significant with p(24)= 0.22.

**Learning Style Differences between Males and Females in CHEM 1P00**

When the modified Kolb learning styles data is sorted by sex, there is not a clear pattern for males versus females, as shown in Figure 17.

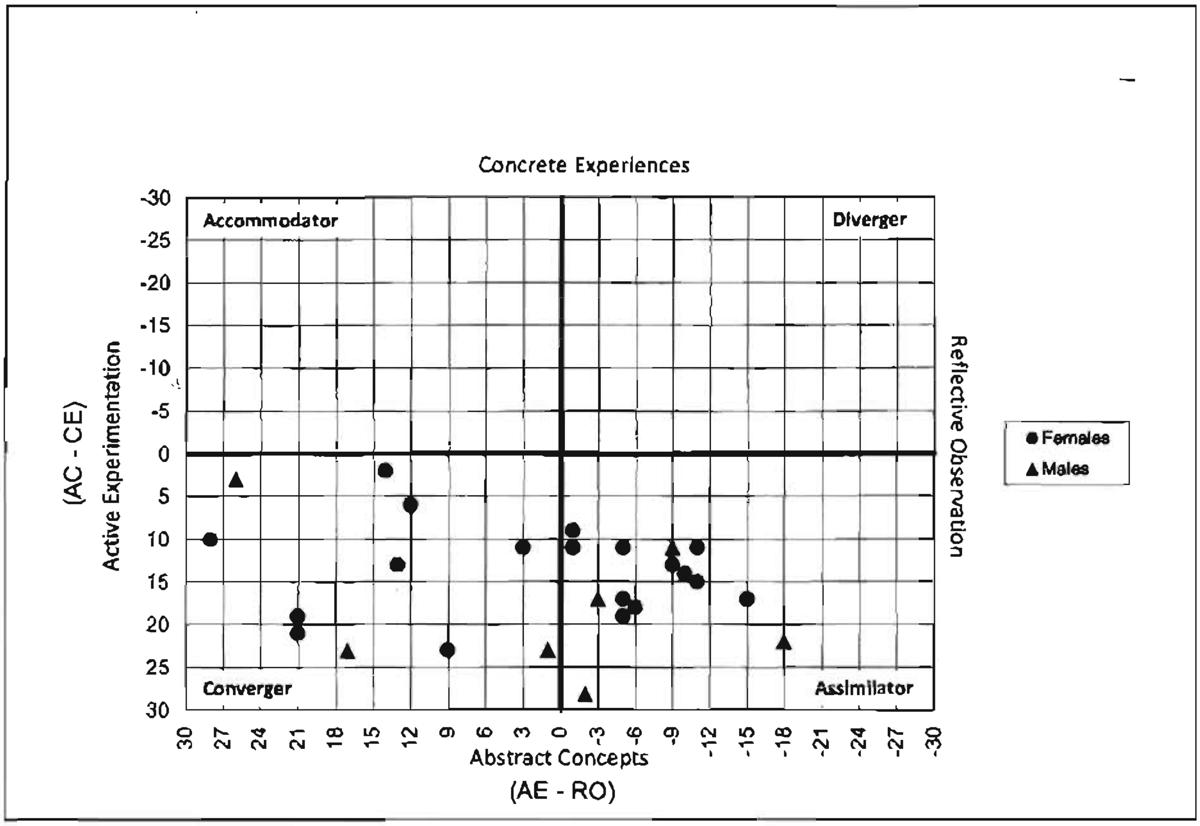


Figure 17. Modified Kolb Learning Styles Inventory data in CHEM 1P00 sorted by sex.

The centroids of the data for females and males in CHEM 1P00 are shown in Figure 18.

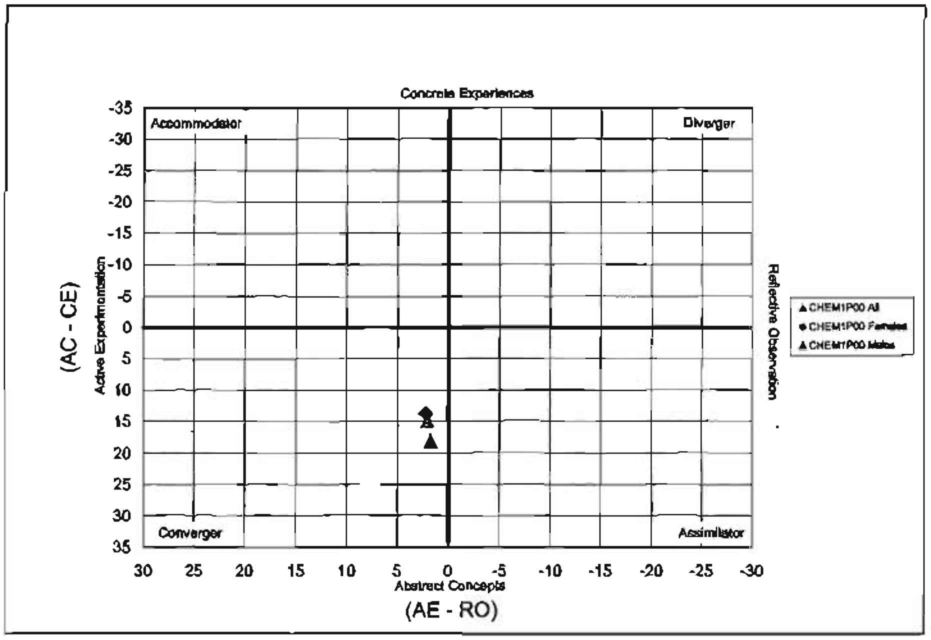


Figure 18. Centroids of data for females, males, and all students in CHEM 1P00.

Analyses of the Kolb LSI data are shown in Table 5. Males' scores in AC were statistically higher than for females (p= 0.01) with a large effect size of 1.32. No other Kolb LSI dimensions showed statistically significant differences between males and females. For females, AC scores correlated positively with course grade achieved, while RO scores correlated negatively with grade achieved. All other correlations for females were not statistically significant. There were no statistically significant correlations for males between Kolb LSI scales and grade achieved in CHEM 1P00 (Table 5).

Table 5. Kolb LSI Data for CHEM 1P00 Sorted By Sex

| CHEM 1P00 | | AC | CE | AC-CE | AE | RO | AE-RO |
|---|---|---|---|---|---|---|---|
| Males (n=7) | Mean | 39.14 | 21.00 | 18.14 | 30.43 | 28.71 | 1.71 |
| | Standard Deviation | 5.24 | 4.69 | 8.57 | 7.00 | 8.94 | 15.07 |
| (df=5) | Correlation to Grade ( r ) | 0.52 | 0.10 | 0.27 | 0.00 | -0.39 | 0.23 |
| (df=5) | t-test for Pearson r (t-value) | 1.36 | 0.22 | 0.62 | 0.00 | -0.94 | 0.53 |
| (df=5) | t-test for Pearson r (p value) | 0.23 | 0.83 | 0.56 | 1.00 | 0.39 | 0.62 |
| Females (n=19) | Mean | 32.79 | 19.11 | 13.68 | 34.89 | 32.68 | 2.21 |
| | Standard Deviation | 4.94 | 3.65 | 5.27 | 6.24 | 8.28 | 12.77 |
| (df=17) | Correlation to Grade ( r ) | 0.61 | 0.30 | 0.37 | 0.11 | -0.50 | 0.38 |
| (df=17) | t-test for Pearson r (t- value) | 3.20 | 1.28 | 1.64 | 0.47 | -2.36 | 1.68 |
| (df=17) | t-test for Pearson r (p value) | 0.01* | 0.22 | 0.12 | 0.64 | 0.03* | 0.11 |
| t-test for difference in LSI scores between males and females (df=24) | t value<br>p value | -2.86<br>0.01* | -1.09<br>0.29 | -1.61<br>0.12 | 1.57<br>0.13 | 1.06<br>0.30 | 0.08<br>0.94 |
| Effect Size (Cohen's d) | | 1.32 | | | | | |

*Note.* *p < 0.05.

## CAEQ Attitudinal Data for CHEM 1P00

Of the 29 students who completed the CAEQ questionnaires in CHEM 1P00, 27 students received a final course grade and competed the attitude section of the CAEQ. A summary of the data is below in Table 6. Overall attitude, attitude regarding chemists, attitude regarding Chemistry research, and attitude regarding Chemistry jobs were found to be significantly different from zero (positive), while attitude regarding Leisure interest in Chemistry was not found to be statistically different from zero. Attitudinal data was not found to be significantly correlated to course grades overall. All subscales of CAEQ attitude data were not statistically significantly correlated to course grades. It is important to note that the data were collected at the very last lecture and only represents approximately 30% of the class still registered in CHEM 1P00, and might not be representative of the CHEM 1P00 class as a whole.

Table 6. CAEQ Class Attitudinal Data for CHEM 1P00

| CHEM 1P00 | Overall Attitude | Chemists Subscale | Chemistry Research Subscale | Leisure Subscale | Chemistry Jobs Subscale |
|---|---|---|---|---|---|
| Mean (n=27) | 0.73 | 0.55 | 1.61 | 0.42 | 0.59 |
| S.D. (n=27) | 0.75 | 0.97 | 0.96 | 1.21 | 1.04 |
| Correlation to Grade (df=25) | 0.17 | 0.25 | 0.02 | -0.20 | 0.30 |
| t-test of Pearson r t- value (df=25) | 0.88 | 1.31 | 0.10 | -1.03 | 1.57 |
| t-test of Pearson r p value (df=25) | 0.39 | 0.20 | 0.92 | 0.31 | 0.13 |
| One sample t-test (difference from zero) t value (df=26) p value (df=26) | 5.07<br><0.0001* | 2.95<br>0.006* | 8.75<br><0.0001* | 1.79<br>0.08 | 2.95<br>0.006* |

*Note.* *p< 0.05
*Note.* Scale ranges from -3 to +3 with negative values denoting negative attitudes and positive values denoting positive attitudes.

**CAEQ Confidence Data for CHEM 1P00**

Of the 29 students who completed the CAEQ questionnaires in CHEM 1P00, 27 students received a final course grade and competed the confidence section of the CAEQ. A summary of their data is shown in Table 7. Statistically significant positive correlations were found to exist between course grade in 1P00 and students' overall confidence, confidence in discussing Chemistry, and confidence using formulas. Statistically significant correlations were not found between course grade in CHEM 1P00 and students' confidence in lab work, confidence in critical thinking, nor their confidence in written answers. It is important to note that the data was collected at the very last lecture and only represents approximately 30% of the class still registered in CHEM 1P00 and might not be representative of the CHEM 1P00 class.

Table 7. CAEQ Class Confidence Data for CHEM 1P00

| CHEM 1P00 | Overall Confidence | Discussing Chemistry Subscale | Lab Work Subscale | Formulas Subscale | Critical Thinking Subscale | Written Answers Subscale |
|---|---|---|---|---|---|---|
| Mean (n=27) | 0.37 | 0.09 | 0.28 | 0.52 | 0.20 | 0.77 |
| S.D. (n=27) | 0.59 | 0.65 | 0.61 | 0.88 | 0.83 | 0.73 |
| Correlation to Grade (df=25) | 0.44 | 0.41 | 0.37 | 0.63 | 0.32 | -0.03 |
| t-test of Pearson r t value (df= 25) | 2.44 | 2.26 | 2.00 | 4.01 | 1.71 | -0.13 |
| t-test of Pearson r p value (df = 25) | 0.02* | 0.03* | 0.06 | $4.8 \times 10^{-4}$* | 0.10 | 0.90 |
| One sample t-test (difference from zero) t value (df=26) | 3.28 | 0.73 | 2.38 | 3.05 | 1.28 | 5.52 |
| p value (df=26) | 0.003* | 0.47 | 0.025* | 0.005* | 0.21 | <0.0001* |

*Note.* *$p < 0.05$.
*Note.* Scale ranges from -2 to +2 with negative values denoting lack of confidence and positive values denoting confidence.

**Differences in Confidence between Males and Females in CHEM 1P00**

Of the 29 students who participated in the research in CHEM 1P00, 27 completed the course to obtain a final grade and completed the confidence section of the CAEQ. Of those, 19 were females and 8 were males. Analysis of the data showed that for females, confidence discussing Chemistry was statistically correlated with course grade. For both males and females, positive correlations were found between confidence using formulas and course grade in CHEM 1P00. Statistically significant differences between males and females were not found in either overall confidence or any of the subscales (Table 8).

Table 8. Overall CAEQ Confidence and CAEQ Confidence Subscales for Males and Females in CHEM 1P00 and Correlation to Final Course Grade

| CHEM 1P00 | Overall Confidence | Discussing Chemistry Confidence | Lab Work Confidence | Formulas Confidence | Critical Thinking Confidence | Written Answers Confidence |
|---|---|---|---|---|---|---|
| Females | | | | | | |
| Mean (n=19) | 0.26 | -0.03 | 0.18 | 0.39 | 0.04 | 0.71 |
| S.D. (n=19) | 0.61 | 0.63 | 0.59 | 0.88 | 0.83 | 0.74 |
| Correlation to Grade (df=17) | 0.44 | 0.50 | 0.37 | 0.64 | 0.30 | -0.01 |
| t-test of Pearson t value (df=17) | 2.03 | 2.37 | 1.66 | 3.47 | 1.30 | -0.04 |
| t-test of Pearson r p value (df=17) | 0.06 | 0.03* | 0.12 | <0.01* | 0.21 | 0.97 |
| Males | | | | | | |
| Mean (n=8) | 0.64 | 0.38 | 0.50 | 0.81 | 0.59 | 0.91 |
| S.D. (n=8) | 0.47 | 0.65 | 0.63 | 0.86 | 0.73 | 0.71 |
| Correlation to Grade (df=6) | 0.62 | 0.21 | 0.51 | 0.74 | 0.61 | -0.10 |
| t-test of Pearson r t value (df=6) | 1.94 | 0.53 | 1.45 | 2.66 | 1.91 | -0.25 |
| t-test of Pearson r p value (df=6) | 0.10 | 0.62 | 0.20 | 0.04* | 0.10 | 0.81 |
| t-test between males (n=8) and females (n=19) | | | | | | |
| t-value (df=25) | -1.56 | -1.49 | -1.25 | -1.13 | -1.64 | -0.63 |
| p value (df=25) | 0.13 | 0.15 | 0.22 | 0.27 | 0.11 | 0.53 |

*Note.* *$p < 0.05$

*Note.* Scale ranges from -2 to +2 with negative values denoting lack of confidence and positive values denoting confidence.

**CAEQ Class Experiences Data for CHEM 1P00**

Of the 29 students who completed the questionnaires, 27 students' final grades and answers for the Experiences section of the CAEQ were available. These data are summarized in Table 9. Although the mean score reported for lecture experiences was a negative value, a statistically significant positive correlation was found between students' grades in CHEM 1P00 and reporting of positive experiences in the lecture. Statistically significant correlations were not found between students' grades in CHEM 1P00 and tutorial experiences and were also not found to exist between course grade in CHEM 1P00 and lab experiences.

Table 9. CAEQ Experiences Data for CHEM 1P00

| CHEM 1P00 | Lecture Experiences | Tutorial Experiences | Lab Experiences |
|---|---|---|---|
| Mean (n=27) | -0.02 | 0.37 | 0.60 |
| S.D. (n=27) | 0.77 | 0.97 | 0.53 |
| Correlation to Grade (df=25) | 0.45 | -0.10 | 0.05 |
| t-test of Pearson r (t-value) (df=25) | 2.52 | -0.51 | 0.25 |
| t-test of Pearson r (p value) (df=25) | 0.018* | 0.615 | 0.805 |
| One sample t-test (difference from zero) | | | |
| t value (df=26) | -0.15 | 1.985 | 5.78 |
| p value (df=26) | 0.88 | 0.06 | <0.0001* |

*Note.* *p< 0.05
*Note.* Scale ranges from -2 to +2 with negative values denoting negative experiences and positive values denoting positive experiences.

## Chemistry 1F92 Data Collected

Of the approximately 400 students who were enrolled over the time that the questionnaires were completed in CHEM 1F92, 243 participants signed consent forms and participated in the research. However, 35 of the 243 students did not complete the course and did not receive a final grade. Data from those 208 students who signed consent forms and completed the course are presented. Data from those students who did not receive a course grade were not included in analyses, except in comparisons of students who withdrew from CHEM 1F92 with those who completed the course. For the 208 students who completed the course, the mean course grade in CHEM 1F92 was 64.17% with a standard deviation of 15.72%.

## Course Achievement for Males and Females in CHEM 1F92

Of the 208 students who completed the course and participated in the research, 99 were male and 109 were female. The mean course grade for the males was 61.68% with a standard deviation of 17.39% while the mean course grade for the females was 66.43% with a standard deviation of 13.72%. This difference does represent a statistically significant difference, $t(206)=2.20$, $p= 0.03$.

## Course Achievement in CHEM 1F92 for First in the Family to Attend University Students versus those who are not First in the Family to Attend University Students

Students were asked in their Demographic Questionnaire (Appendix F) to identify if they were the first in their family to attend university. Of the 208 students who completed the course and participated in the research, 73 were FFS and 134 were NFFS. One student did not complete this question regarding family education background. Table 10 shows the number of students who are first in their immediate family to attend university and those who are not, and the mean grade in CHEM 1F92 earned by each group. The mean grade for the FFS was 63.14% with a standard deviation of 15.37% while the NFFS had a mean grade of 64.69% and a standard deviation of 15.98%. These differences were not statistically significant t(205)= -0.68, p=0.49.

Table 10. Academic Achievement in CHEM 1F92 and Family University Experience

| Category | Mean Course Grade | Standard Deviation | Number of Students |
|---|---|---|---|
| First in the Family to Attend University | 63.14% | 15.37% | 73 |
| Non-First in the Family to Attend University | 64.69% | 15.98% | 134 |

**CHEM 1F92 Modified Kolb Learning Styles Inventory Data**

Of the 208 students who completed the course, 37 did not complete the Modified Kolb Learning Styles Inventory correctly or completely. Therefore, data are presented for the 171 students who completed all of the Modified Kolb LSI correctly and achieved a final course grade. The results of the CHEM 1F92 Modified Kolb Learning Styles Inventory, according to final grade achieved are presented in Figure 19 with centroids for each grade range shown in Figure 20.

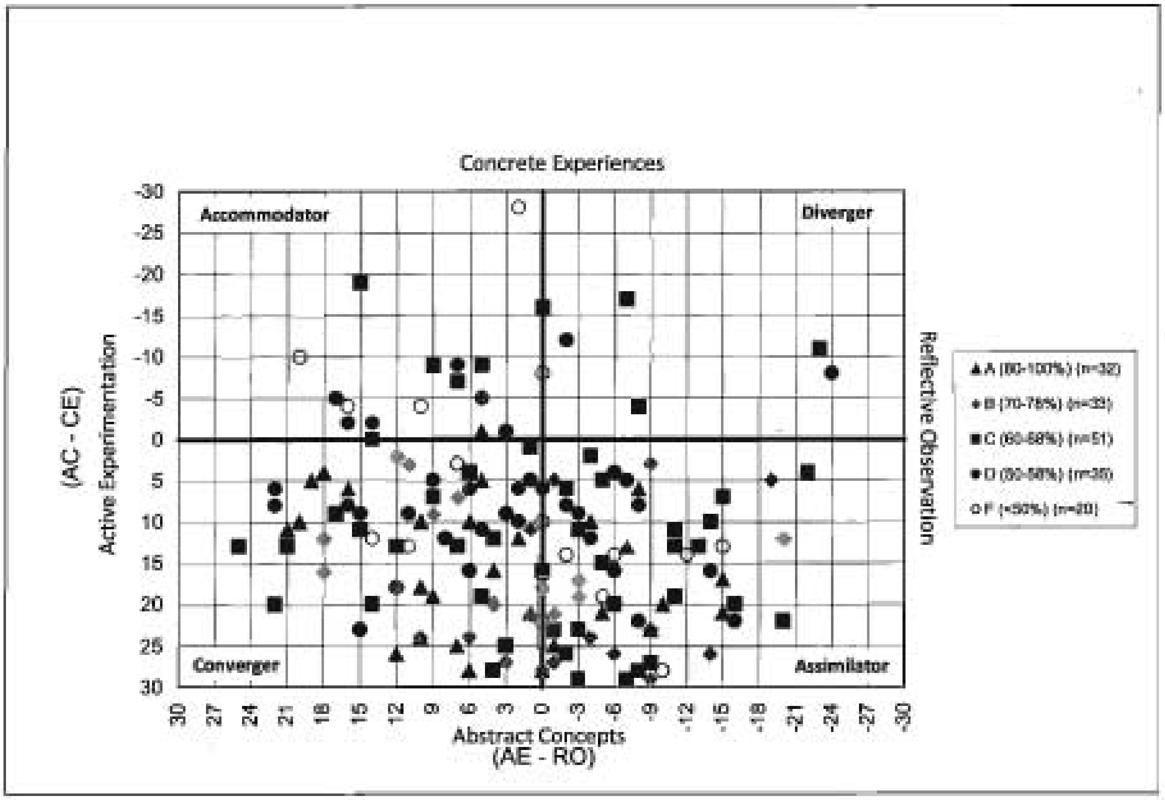


Figure 19. Kolb Learning Styles Inventory data for the CHEM 1F92 Chemistry class showing final grade achieved.

*Note.* There is overlap at some points, and therefore, 171 individual data points are not visible.

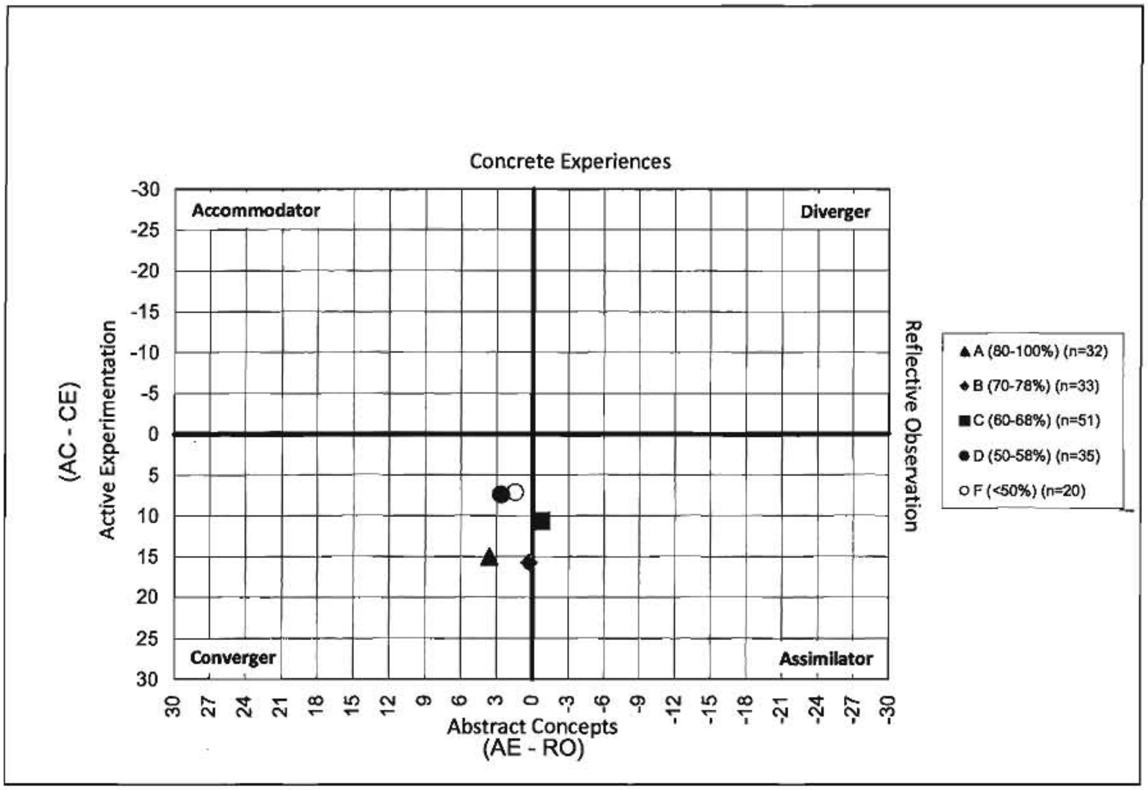


Figure 20. Centroids of Kolb Learning Styles Inventory data for the CHEM 1F92 Chemistry class by grade level.

Definitive numbers of students in each category cannot be determined as some students have either AE-RO scores that are zero or AC-CE scores of zero. These students straddle two quadrants, and consequently two learning styles, and can therefore not be assigned to one specific learning style.

Single sample t-tests show that AC-CE scores differed significantly from zero, $t(170)= 13.32$, $p<0.0001$ while AE-RO scores did not differ significantly from zero, $t(170)= 1.52$, $p= 0.13$. This shows that CHEM 1F92 students favoured abstract learning over concrete learning but that there was not a statistically significant preference between AE and RO.

When the grade levels are looked at independently, trends emerge with respect to learning styles and academic achievement. Notably, 23 students in the Accommodator and Diverger categories were in the <50%, 50-58%, and 60-68% ranges (there is overlap at one point, and therefore, only 22 points are shown) and only three students in the Accommodator and Diverger categories achieved final course grades of 70% or greater.

Each LSI dimension (AC, CE, AE, and RO) and the AE-RO and AC-CE scores were analyzed with respect to correlation to grade achieved in CHEM 1F92. CE scores were significantly and negatively correlated with course grades, while AC and AC-CE scores were significantly positively correlated with course grade (Table 11). AE, RO, and AE-RO scores did not have statistically significant correlations to course grade.

Table 11. Correlations of Kolb LSI Dimensions to Grade Achieved for CHEM 1F92 Class Data

| CHEM 1F92 | AC | CE | AC-CE | AE | RO | AE-RO |
|---|---|---|---|---|---|---|
| Mean (n=171) | 33.02 | 21.63 | 11.39 | 33.30 | 32.07 | 1.23 |
| Standard Deviation (n=171) | 7.36 | 5.77 | 11.18 | 6.81 | 5.94 | 10.64 |
| Correlation to Grade ( r ) (df= 169) | 0.28 | -0.25 | 0.31 | -0.03 | -0.07 | 0.02 |
| t-test for Pearson r t value (df= 169) | 3.75 | -3.30 | 4.23 | -0.44 | -0.87 | 0.20 |
| t-test for Pearson r p value (df= 169) | <0.001* | <0.001* | <0.001* | 0.66 | 0.39 | 0.84 |

*Note.* *$p < 0.05$

**Kolb Learning Styles by Sex in CHEM 1F92**

Of the 171 students who completed the modified Kolb LSI correctly and completely, 93 students were females and 78 students were males. Analysis of the Kolb LSI data show that statistically significant positive correlations were found between males' course grades and AC as well as males' course grades and AC-CE (Table 12). Statistically significant negative correlations were found between males' course grades and CE scores. For females, statistically significant positive correlations were found between course grades and AC scores as well as course grades and AC-CE scores. Negative correlations of course grades for the females with CE scores approached statistical significance ($p=0.06$). Correlations of AE, RO, and AE-RO with course grade were not statistically significant for either males or females.

Analysis with an independent samples t-test showed statistically significant differences between males and females in CE scores $t(169)=2.38$, $p=0.02$, and RO scores $t(169)=2.97$, $p<0.01$, with males scoring higher in CE and females scoring higher in RO. Statistically significant differences were not found between males and females for AC, AC-CE, AE and AE-RO.

Table 12. Kolb LSI Data for CHEM 1F92 Sorted by Sex

| CHEM 1F92 | | Total AC | Total CE | AC-CE | Total AE | Total RO | AE-RO |
|---|---|---|---|---|---|---|---|
| Males (n=78) | Mean | 34.01 | 22.76 | 11.26 | 32.60 | 30.63 | 1.97 |
| | S.D. | 8.30 | 5.86 | 12.37 | 7.11 | 5.61 | 10.52 |
| | Correlation to Grade ( r ) (df=76) | 0.27 | -0.26 | 0.30 | -0.004 | -0.12 | 0.06 |
| t-test for Pearson r | t value (df=76) | 2.40 | -2.35 | 2.75 | -0.03 | -1.01 | 0.52 |
| t-test for Pearson r | p value (df=76) | 0.02* | 0.02* | <0.01* | 0.97 | 0.32 | 0.60 |
| Females (n=93) | Mean | 32.18 | 20.68 | 11.51 | 33.89 | 33.28 | 0.61 |
| | S.D. | 6.40 | 5.54 | 10.14 | 6.52 | 5.97 | 10.75 |
| | Correlation to Grade ( r ) (df=91) | 0.34 | -0.20 | 0.32 | -0.10 | -0.08 | -0.01 |
| t-test for Pearson r | t value (df=91) | 3.48 | -1.9 | 3.25 | -0.92 | -0.80 | -0.11 |
| t-test for Pearson r | p value (df=91) | <0.01* | 0.06 | <0.01* | 0.36 | 0.43 | 0.91 |
| t-test between males and females | t value (df=169) | -1.63 | -2.38 | 0.14 | 1.24 | 2.97 | -0.83 |
| | p value (df=169) | 0.10 | 0.02* | 0.89 | 0.22 | <0.01* | 0.40 |
| Effect size | Cohen's d | 0.25 | 0.37 | 0.02 | 0.19 | 0.45 | 0.13 |

*Note*. *p < 0.05

The CHEM 1F92 students' Kolb LSI data are shown in Figure 21 separated by sex with the centroids of the data plotted. The male centroid has xy coordinates at 1.97, 11.26 while the xy coordinates of the female centroid are 0.61, 11.51.

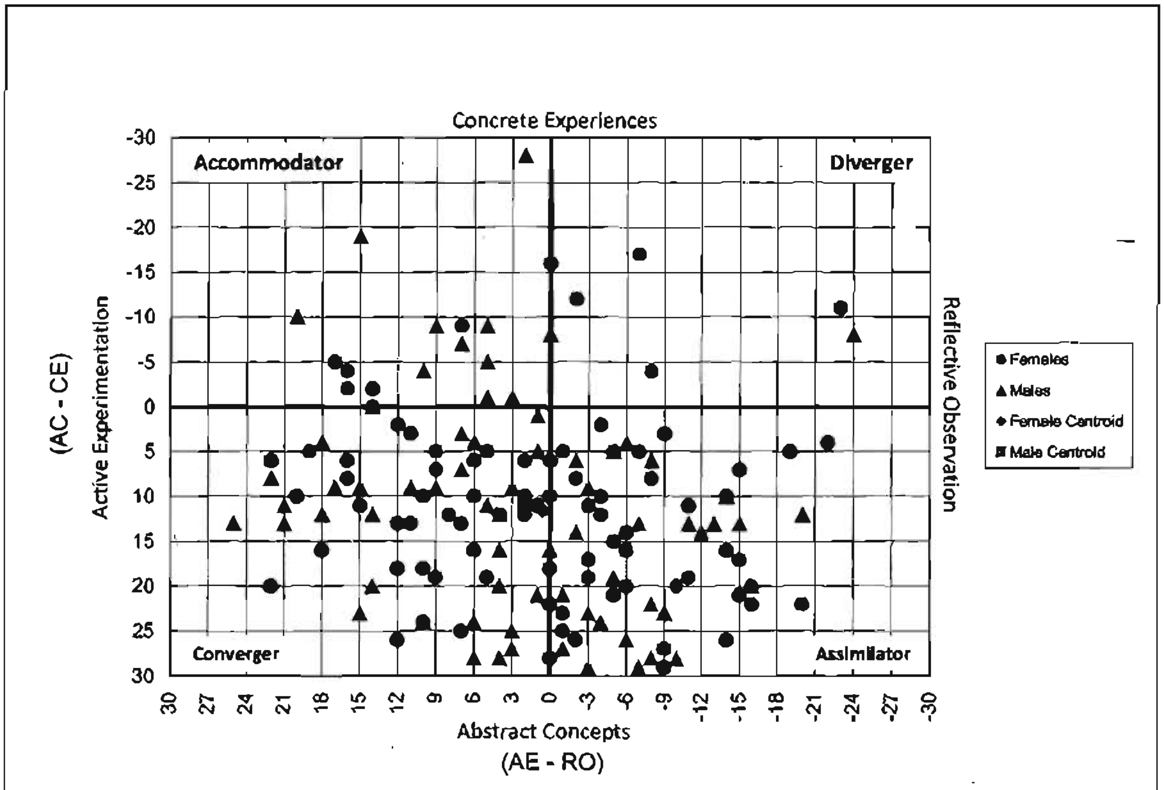


Figure 21. Kolb Learning Style Inventory data for CHEM 1F92 students separated by sex.

## Kolb Learning Style Differences between FFS and NFFS in CHEM 1F92

Of the 208 students who participated in the research in CHEM 1F92 and completed the course, 37 did not complete the Modified Kolb Learning Styles Inventory completely or correctly. Of the 171 students who did complete the Modified Kolb LSI correctly, 60 were FFS, 110 were NFFS, and one student did not provide data on family educational background. Data for the 170 students who completed the course, completed the Kolb LSI completely and correctly, and provided family educational data are shown in Table 13. No statistically significant correlations were found between grade achieved in CHEM 1F92 and any dimension of the Kolb LSI for FFS. However, for NFFS, statistically significant positive correlations were found between course grade achieved in CHEM 1F92 and the factors AC and AC-CE while a statistically significant negative correlation was found between course grade achieved in CHEM 1F92 and CE score. No statistically significant differences were found between FFS and NFFS regarding modified Kolb LSI data in CHEM 1F92.

Table 13. Kolb LSI Dimensions for CHEM 1F92 by Family Educational Background

| CHEM 1F92 | | Total AC | Total CE | AC-CE | Total AE | Total RO | AE-RO |
|---|---|---|---|---|---|---|---|
| FFS (n=60) | Mean | 33.73 | 21.07 | 12.67 | 32.57 | 32.63 | -0.07 |
| | S.D. | 6.87 | 5.75 | 10.41 | 7.16 | 5.82 | 10.87 |
| | Correlation to Grade ( r ) | 0.09 | 0.00 | 0.06 | 0.04 | -0.16 | 0.11 |
| | t-test for Pearson r t value (df=58) | 0.68 | 0.02 | 0.44 | 0.33 | -1.23 | 0.88 |
| | t-test for Pearson r p value (df=58) | 0.50 | 0.98 | 0.66 | 0.74 | 0.22 | 0.38 |
| NFFS (n=110) | Mean | 32.52 | 21.96 | 10.55 | 33.74 | 31.81 | 1.93 |
| | S.D. | 7.56 | 5.79 | 11.51 | 6.63 | 6.02 | 10.54 |
| | Correlation to Grade ( r ) | 0.36 | -0.37 | 0.43 | -0.08 | -0.02 | -0.04 |
| | t-test for Pearson r t value (df=108) | 4.08 | -4.16 | 4.9 | -0.81 | -0.18 | -0.4 |
| | t-test for Pearson r p value (df=108) | <0.01* | <0.01* | <0.01* | 0.42 | 0.86 | 0.69 |
| Difference between FFS and NFFS | t-test t value (df=168) | 1.03 | -0.97 | 1.18 | -1.07 | 0.86 | -1.17 |
| Difference between FFS and NFFS | t-test p value (df=168) | 0.30 | 0.33 | 0.24 | 0.29 | 0.39 | 0.24 |

*Note.* *p < 0.05

**Differences among Failures and Withdrawals for Males and Females not completing CHEM 1F92**

Of those participating in the research in CHEM 1F92, 60 students did not successfully complete the course either because they chose to withdraw from the course or because they received a failing grade (Table 14). Of those who did not pass CHEM 1F92, the Chi-Square Test of Independence shows that there is a statistically significant difference between males and females in terms of withdrawing from the course and failures in CHEM 1F92, $\chi^2(1)= 9.38$, p=0.0022. This Chi-Square value reported (df=1) is the Yates Chi-Square, corrected for continuity. The Pearson Chi-Square, uncorrected for continuity, is 11.05, p=0.0009.

Table 14. Number of Students who Withdrew or Failed CHEM 1F92 Sorted by Sex

| CHEM 1F92 | Males | Females | Totals |
|---|---|---|---|
| Withdrew or Dropped | 10 | 25 | 35 |
| Fail | 18 | 7 | 25 |
| Total | 28 | 32 | 60 |

**CAEQ Attitude Data for CHEM 1F92**

Of the 208 students who obtained a course grade and participated in the research, data for the Attitudes scale of the CAEQ was collected for all 208 students. The results are presented in Table 15. Overall attitude, as well as each of the attitude subscales, was found to be significantly different from zero (positive). No statistically significant correlation was found between overall attitude and final course grade in CHEM 1F92, nor between any of the subscales and final course grade in CHEM 1F92.

Table 15. CHEM 1F92 CAEQ Attitudinal Class Data and Correlation with Course Grade

| CHEM 1F92 | Overall Attitude | Chemists Subscale | Chemistry Research Subscale | Leisure Subscale | Chemistry Jobs Subscale |
|---|---|---|---|---|---|
| Mean (n=208) | 1.04 | 0.97 | 1.95 | 0.29 | 1.06 |
| S.D. (n=208) | 0.75 | 0.85 | 0.91 | 1.31 | 1.02 |
| Correlation to course Grade (df=206) | 0.04 | 0.06 | 0.02 | 0.04 | -0.03 |
| t-test of Pearson r t value (df=206) | 0.58 | 0.86 | 0.30 | 0.58 | -0.49 |
| t-test of Pearson r p value two-tailed (df=206) | 0.56 | 0.39 | 0.76 | 0.56 | 0.62 |
| One sample t-test (difference from zero) | | | | | |
| t value (df=207) | 20.13 | 16.52 | 31.07 | 3.24 | 15.06 |
| p value (df=207) | <0.0001* | <0.0001* | <0.0001* | 0.001* | <0.0001* |

*Note.* *p < 0.05
*Note.* Scale ranges from -3 to +3 with negative values denoting negative attitudes and positive values denoting positive attitudes.

**CHEM 1F92 CAEQ Class Confidence Data**

Of the 208 students who obtained a course grade in CHEM 1F92 and participated in the research, two did not provide confidence data. Confidence data for the 206 students are provided in Table 16. Statistically significant positive correlations were found between course grade in CHEM 1F92 and overall confidence, confidence discussing Chemistry, confidence using formulas, and critical thinking about Chemistry. No statistically significant correlations were found between course grade achieved in CHEM 1F92 and lab work confidence or confidence in providing written answers.

Table 16. CHEM 1F92 CAEQ Class Confidence Data and Correlation with Final Course Grade

| CHEM 1F92 | Overall Confidence | Discussing Chemistry Confidence | Lab Work Confidence | Using Formulas Confidence | Critical Thinking Confidence | Written Answers Confidence |
|---|---|---|---|---|---|---|
| Mean (n=206) | 0.52 | 0.28 | 0.47 | 0.73 | 0.46 | 0.68 |
| SD (n=206) | 0.57 | 0.78 | 0.70 | 0.68 | 0.69 | 0.69 |
| Correlation to Grade (df=204) | 0.20 | 0.23 | 0.04 | 0.26 | 0.14 | 0.12 |
| t-test of Pearson r t-value (df=204) | 2.88 | 3.41 | 0.58 | 3.88 | 1.97 | 1.67 |
| t-test of Pearson r p value (df=204) | <0.01* | <0.01* | 0.56 | <0.01* | 0.05* | 0.10 |
| One sample t-test (difference from zero) | | | | | | |
| t value (df=205) | 13.2146 | 5.1463 | 9.6448 | 15.3166 | 9.6736 | 14.0541 |
| p value (df=205) | <.0001* | <.0001* | <.0001* | <.0001* | <.0001* | <.0001* |

*Note.* *$p < 0.05$
*Note.* Scale ranges from -2 to +2 with negative values denoting lack of confidence and positive values denoting confidence.

**Differences in CAEQ Measures of Confidence between Males and Females Taking CHEM 1F92**

Of the 208 students who obtained a course grade in CHEM 1F92 and participated in the research, two did not provide confidence data. Of the 206 students whose data was available, 109 were females and 97 were males. Data from the CAEQ section on

Confidence are provided in Table 17. Statistically significant positive correlations were found for both males and females between grade achieved in CHEM 1F92 and overall confidence, confidence discussing Chemistry, and confidence using formulas. Statistically significant correlations were not found between course grade and the following: confidence regarding lab work, critical thinking confidence, and confidence providing written answers.

In CHEM 1F92, males were found to be significantly more confident than females in terms of their overall confidence, their confidence discussing Chemistry, their confidence regarding lab work, confidence using formulas, and confidence in critical thinking. The difference between confidence among males and females regarding written answers approached statistical significance ($p= 0.06$) with females reporting higher confidence in this subscale.

Table 17. Differences between Males and Females in CHEM 1F92 in Confidence Means as Measured by the CAEQ

| | Males (n=97) (df=95) | | | | | Females (n=109) (df=107) | | | | | t-test of Male vs. Female Scores (df=204) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CHEM 1F92 | Mean | S.D. | Correlation to Grade ( r ) | t value | p value | Mean | S.D. | Correlation to Grade ( r ) | t value | p value | t value | p value | Cohen's d |
| Overall Confidence | 0.65 | 0.51 | 0.29 | 2.94 | <0.01* | 0.41 | 0.60 | 0.19 | 2.04 | 0.04* | -3.05 | <0.01* | 0.43 |
| Discussing Chemistry Confidence | 0.49 | 0.77 | 0.36 | 3.79 | <0.01* | 0.09 | 0.74 | 0.19 | 2.00 | 0.05* | -3.82 | <0.01* | 0.53 |
| Lab Work Average | 0.72 | 0.64 | 0.12 | 1.16 | 0.25 | 0.25 | 0.68 | 0.07 | 0.74 | 0.46 | -5.06 | <0.01* | 0.71 |
| Formulas Average | 0.88 | 0.57 | 0.33 | 3.37 | <0.01* | 0.60 | 0.75 | 0.30 | 3.20 | <0.01* | -2.99 | <0.01* | 0.42 |
| Critical Thinking Average | 0.58 | 0.65 | 0.16 | 1.61 | 0.11 | 0.36 | 0.70 | 0.17 | 1.75 | 0.08 | -2.34 | 0.02* | 0.33 |
| Written Answers Average | 0.58 | 0.70 | 0.12 | 1.16 | 0.25 | 0.76 | 0.67 | 0.08 | 0.80 | 0.43 | 1.90 | 0.06 | -0.26 |

*Note.* *$p < 0.05$
*Note.* Scale ranges from -2 to +2 with negative values denoting lack of confidence and positive values denoting confidence.

**CHEM 1F92 CAEQ Experiences Data**

Tutorials were not part of the CHEM 1F92 course at the time that the surveys were completed and therefore the section regarding tutorial experiences was not included in the questionnaires. As data were collected early in the academic year, the students in CHEM 1F92 had only had an opportunity to experience a limited number of lectures and only one or two labs. It was decided that this limited number of experiences was insufficient for students to have formed an accurate assessment of these experiences at such an early stage in the course. Therefore, the CHEM 1F92 students were also not asked about their experiences in lectures or laboratories.

**Pressure to Succeed and Class Data**

Of the 208 students who participated in the research and obtained a course grade, self-reported pressure to succeed from their families was reported for 207 students. Students were asked to self-report on a Likert scale from 1-5 how much pressure they experienced from their families to be successful in CHEM 1F92 with 1 corresponding to no pressure and 5 corresponding to a great deal of pressure. The mean score for students was 3.60 with a standard deviation of 1.08. The correlation to course grade of -0.03 was not found to be statistically significant, $t(205)= -0.46$, $p= 0.64$.

**Differences in Pressure to Succeed for Males and Females in CHEM 1F92**

Students were asked to self-report on a Likert scale from 1-5 how much pressure they experienced from their families to be successful in CHEM 1F92 with 1 corresponding to no pressure and 5 corresponding to a great deal of pressure. Of the 207 students who completed the course and provided data on pressure to succeed, 98 were males and 109 were females. Males reported a mean pressure to succeed of 3.69 with a standard deviation of 1.12 while females reported a mean pressure to succeed of 3.71 with a standard deviation of 1.05 (Table 18.) There was no statistically significant correlation of pressure to succeed with course grade achieved for either males or females. A t-test showed that there was no statistically significant difference between pressure to succeed for males and pressure to succeed for females, t(205)= -0.05, p= 0.96.

Table 18. Differences in Pressure to Succeed for Males and Females in CHEM 1F92

| CHEM 1F92 | Males (n=98) | CHEM 1F92 | Females (n=109) |
|---|---|---|---|
| Mean Pressure to Succeed | 3.69 | Mean Pressure to Succeed | 3.71 |
| S.D. | 1.12 | S.D. | 1.05 |
| Correlation to Grade (df=96) | 0.07 | Correlation to Grade (df=107) | 0.01 |
| t-test of Pearson r (t-value) (df=96) | -0.69 | t-test of Pearson r (t-value) (df=107) | 0.12 |
| t–test of Pearson r (p value) (df=96) | 0.49 | t–test of Pearson r (p value) (df=107) | 0.90 |

**Differences in Pressure to Succeed between FFS and NFFS in CHEM 1F92**

Students were asked to self-report on a Likert scale from 1-5 how much pressure they experienced from their families to be successful in CHEM 1F92 with 1 corresponding to no pressure and 5 corresponding to a great deal of pressure. Of the 207 students who completed the course and reported pressure to succeed data, 73 were FFS and 134 were NFFS. No statistically significant differences were found between FFS who reported a mean pressure to succeed of 3.53 with a standard deviation of 1.18 as compared to NFFS who reported a mean pressure to succeed score of 3.79 with a standard deviation of 1.01 (p=0.09). Pressure to succeed was not correlated to course grade achieved for either FFS or NFFS (Table 19).

Table 19. Self-Reported Pressure to Succeed for FFS versus NFFS in CHEM 1F92 and Correlation to Final Course Grade

| CHEM 1F92 | NFFS (n=134) | | FFS (n=73) |
|---|---|---|---|
| Mean Self-Reported Pressure to Succeed | 3.79 | Mean Self-Reported Pressure to Succeed | 3.53 |
| S.D. | 1.01 | S.D. | 1.18 |
| Correlation to Final Course Grade (df=132) | 0.04 | Correlation to Final Course Grade (df=71) | -0.17 |
| t-test of Pearson r t value (df=132) | 0.46 | t-test of Pearson r t value (df=71) | -1.41 |
| t-test of Pearson r p value (df=132) | 0.65 | t-test of Pearson r p value (df=71) | 0.16 |

*Note.* Pressure to succeed scale ranges from 1 to 5 with 1 signifying low pressure to succeed and 5 signifying a great deal of pressure to succeed.

**Living Arrangements and Academic Achievement in CHEM 1F92**

Of the 243 students in CHEM 1F92 who participated in the research, living arrangements data was available for 239; 4 did not provide living arrangements data, one of which did not complete the course to receive a grade. Of the 239 for whom living arrangements data was provided, 34 did not complete the course to receive a final grade. Therefore, both grade information and living arrangements information was available for

205 students. Data regarding living arrangements and final course grade achieved are shown in Table 20.

One way ANOVA analysis of students in the three living arrangements of with family, off-campus but not with family, and residence showed that the mean course grades achieved by each group were not statistically equal, $F(2)=7.35$, $p= 8.3 \times 10^{-4}$.

Statistical analysis using t-tests shows that students who lived with their families did achieve higher grades in CHEM 1F92 than those who lived off-campus (but not with family) ($p= <0.01$) with a moderately strong effect size of 0.61. Students living with their families also had a statistically significantly higher mean that those who lived in residence ($p= <0.01$) with a moderate effect size of 0.41. Statistically significant differences were not found between students who lived off-campus and those who lived in residence ($p= 0.26$) (Table 20).

Table 20. Living Arrangements of Students in CHEM 1F92 and Mean Course Grades

| Living Arrangements during academic year | Average Grade in CHEM 1F92 (%) | S.D. | t-tests | t-test p value | Effect Size (Cohen's d) |
|---|---|---|---|---|---|
| With family (n=93) | 68.54 | 16.92 | Family vs. Off-campus (df=135) | <0.01* | 0.61 |
| Off-campus, but not with family (n=44) | 58.73 | 14.13 | Off-campus vs. Residence (df=110) | 0.26 | -0.22 |
| Residence (n=68) | 61.79 | 13.72 | Family vs. Residence (df=159) | <0.01* | 0.43 |

*Note.* *p < 0.05

Of those who participated in the research, 208 students completed the course, however living arrangements data was only available for 205. Of the 35 students who withdrew, living arrangements data was available for 34 students. The Chi-Square Test of Independence showed students' living arrangements were not correlated with whether or not they completed CHEM 1F92 (Table 21); $\chi^2(2)=0.47$, p=0.79.

Table 21. Student Living Arrangements in CHEM 1F92 and Completion or Withdrawal from the Course

| | 1F92 Living Arrangements | | |
|---|---|---|---|
| | Family | Off Campus | Residence |
| Completed CHEM 1F92 | 93 | 44 | 68 |
| Withdrew from CHEM 1F92 | 15 | 9 | 10 |

Of the 205 students who completed CHEM 1F92, 180 passed and 25 failed (Table 22). The Chi-Square Test of Independence showed that students' living arrangements were not correlated with whether or not they passed or failed CHEM 1F92; $\chi^2(2)=0.36$, $p=0.84$.

Table 22. Student Living Arrangements in CHEM 1F92 and Number who Passed and Failed the Course

| | 1F92 Living Arrangements | | |
|---|---|---|---|
| Course Achievement in CHEM 1F92 | Family | Off Campus | Residence |
| Passed | 81 | 38 | 61 |
| Failed | 12 | 6 | 7 |

Of the 205 students who did complete CHEM 1F92, 35 earned a grade of 80% or higher, while 170 earned less than 80%. Analysis using the Chi-Square Test of Independence showed that for the three different living arrangements, the probability of earning 80% or more was not equal with $\chi^2(2)= 17.2$, $p= 0.0002$. Of those who earned 80% or higher, 27 lived with family, while 3 lived off-campus but not with family, and 5 lived in residence (Table 23).

Table 23. Student Living Arrangements in CHEM 1F92 and Number who Achieved 80% or Greater as a Final Course Grade and Number who Achieved <80% as a Final Course Grade

| | 1F92 Living Arrangements | | |
|---|---|---|---|
| Course Grade Achieved in CHEM 1F92 | Family | Off Campus | Residence |
| > = 80% | 27 | 3 | 5 |
| < 80% | 66 | 41 | 63 |

Previous research (U.S. Department of Education, 1998) reported that FGS were more likely to live with family or off-campus, and less likely to live on campus as compared to NFGS. Analysis with the Chi-Square Test of Independence showed that for FFS versus NFFS in CHEM 1F92, these differences were not found, $\chi^2(1)= 0.95$, $p= 0.33$ (Table 24). The Chi-Square value reported (df=1) is the Yates Chi-Square, corrected for continuity. The Pearson Chi-Square, uncorrected for continuity, is 1.25, $p=0.26$.

Table 24. Number of Students in CHEM 1F92 Living in Residence or not in Residence Sorted by Family Educational Background

| CHEM 1F92 | Number of students in residence | Number of students living off-campus or with family |
|---|---|---|
| FFS | 25 | 64 |
| NFFS | 54 | 100 |

**Chemistry CHEM 2P20 Data Collected**

One hundred and forty students participated in the research while taking CHEM 2P20. Data were collected from CHEM 2P20 courses in Spring 2008 (13 of 17 students present completed the surveys and all 13 completed the course to earn a grade), Spring 2009 (15 of 18 students present at the final lecture completed the surveys, grades were available for 14 students) and during the first tutorials of the Fall 2009-2010 term (112 students of the 115 who were present in the tutorials participated, however, 15 did not earn a grade, leaving 97 who did complete the course). In total, 124 students completed CHEM 2P20 and were assigned a grade, while 16 of the 140 students who participated did not complete the course.

Therefore, the overall participation among these three sections of the course was 140 of 150 students who were present when the surveys were completed or 93.3% participation. However, data was only analyzed for the 124 students who completed the course to earn a grade. Therefore the data analyzed represents 82.7% of the class who were present during the three administrations of the questionnaires (124 students of 150 present). The overall mean course grade for students taking CHEM 2P20 was 62.66% with a standard deviation of 13.02%.

**CHEM 2P20 Spring Courses versus CHEM 2P20 Fall-Winter Courses**

The CHEM 2P20 students who completed the surveys in Spring 2008 and completed the course to obtain a final grade (thirteen students) had a mean grade of 67.46% with a standard deviation of 9.47%. The fourteen CHEM 2P20 students who participated in the surveys and completed the course in Spring 2009 had a mean grade of 73.57% with a standard deviation of 10.84%. The 97 students who participated in the research and completed the course to obtain a final grade in the Fall-Winter class had a mean grade of 60.44% with a standard deviation of 12.84%. Analysis of variance found these differences statistically significant with $F_{(2, 121)} = 8.02$, $p < 0.01$. When the 27 students who completed the surveys while in the Spring term were compared to those who completed CHEM 2P20 in the Fall term, analysis of variance found statistically significant differences, $F_{(1, 122)} = 14.32$, $p < 0.01$. It is not known whether more motivated students take the Spring course, having fewer courses to devote one's attention to, or other factors may have resulted in the increased means for the Spring sessions. However, since the Spring courses consist of students who could have taken CHEM 2P20 in Fall-Winter, all CHEM 2P20 students were grouped together for analysis.

## Mean Course Grades of Males and Females in CHEM 2P20

Of the 124 students who completed CHEM 2P20 to receive a course grade, 63 were males and 61 were females. The mean course grade for males was 62.83% with a standard deviation of 12.61% while the females had a mean course grade of 62.49% and a standard deviation of 13.54%. There was no statistically significant difference in course grades achieved by males and females in CHEM 2P20, $t(122)= 0.14$, $p=0.89$.

## Mean Course Grades of FFS and NFFS in CHEM 2P20

Of the 124 students who completed CHEM 2P20 to receive a course grade, 38 were FFS and 86 were NFFS. The mean grade for FFS was 60.32% with a standard deviation of 15.08% while NFFS had a mean course grade of 63.70% with a standard deviation of 11.96%. There was no statistically significant difference in grades between FFS and NFFS in CHEM 2P20, $t(122)= 1.34$, $p= 0.18$.

## Kolb Learning Styles Data for CHEM 2P20

In total, 140 students participated in the research while taking CHEM 2P20, but 16 students withdrew from the course after the surveys were completed; 9 females and 7 males. The data from those 16 students are not included in the analysis. As well, 14 students did not complete the Kolb LSI completely and correctly and therefore their data are not included in the analysis. Students who did not complete the course to receive a final grade are also not included in the analysis. Data are presented in Figures 22 and 23 for the 110 students who completed the modified Kolb LSI completely and correctly, and who completed CHEM 2P20 to obtain a final course grade.

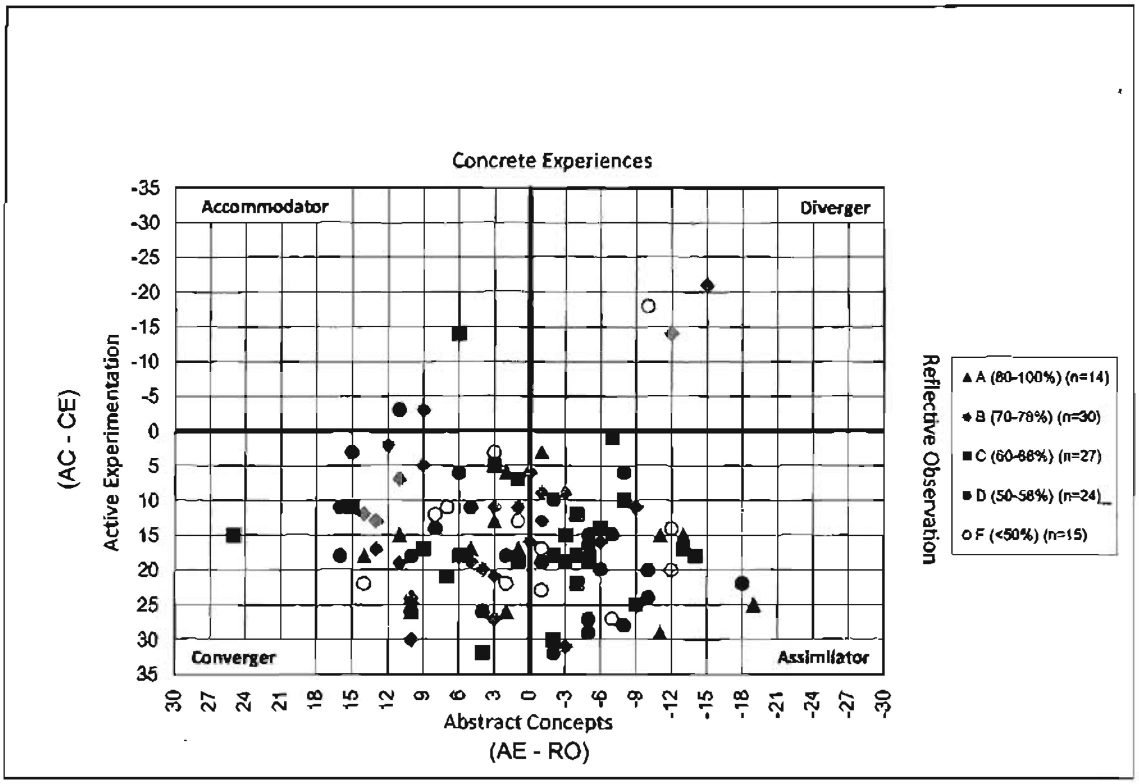


Figure 22. Kolb Learning Styles data for the 110 students in CHEM 2P20 who completed the modified Kolb LSI and received a course grade.

Note. Each of the following coordinates had two students; (1,7), (5,11), (-4,12), (-5,17), (10,18), (-5,19), (-3,19), (-4,22), (10,24), (10,26), and (-3,31).

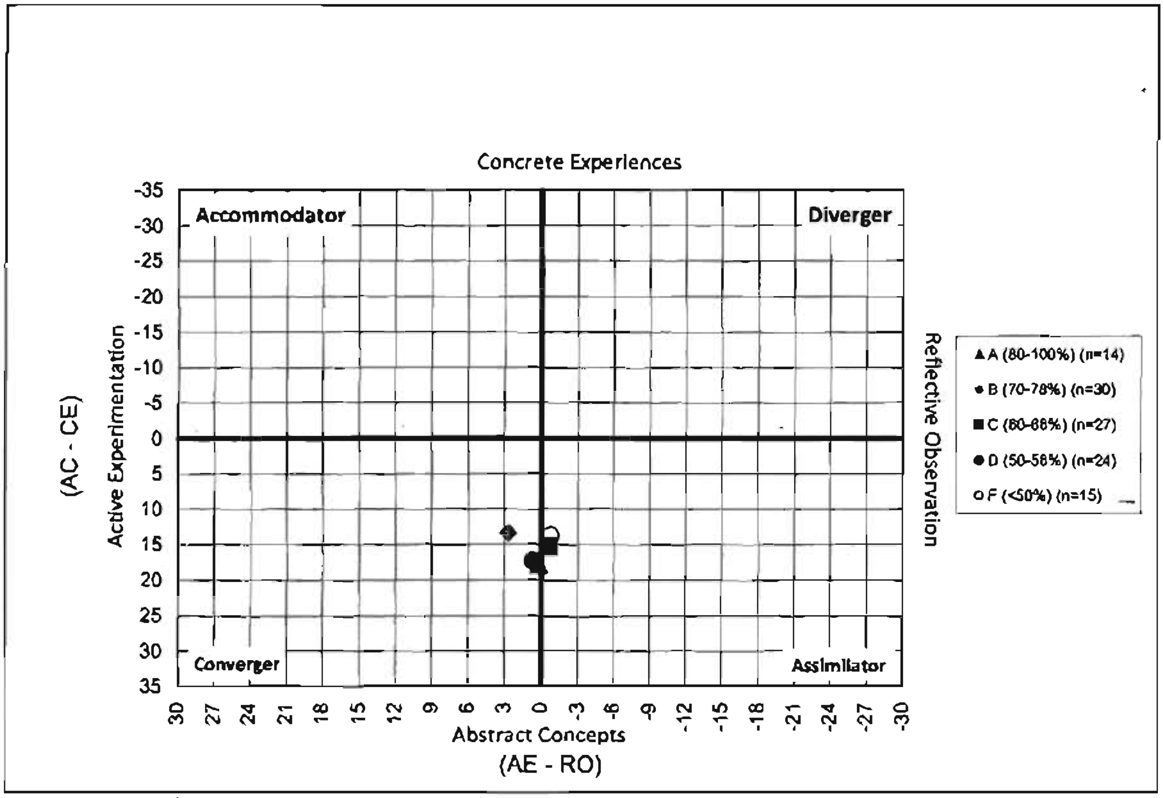


Figure 23. Kolb Learning Styles centroids by letter grade for the 110 students who completed the modified Kolb LSI while in CHEM 2P20 and completed the course to receive a final course grade.

When analyzed statistically, no significant correlations were found between course grade in CHEM 2P20 and AC, CE, AC-CE, AE, RO, or AE-RO (Table 25).

Table 25. Modified Kolb LSI Data for CHEM 2P20

| CHEM 2P20 | Total AC | Total CE | AC-CE | Total AE | Total RO | AE-RO |
|---|---|---|---|---|---|---|
| Average (n=110) | 35.65 | 20.35 | 15.30 | 32.24 | 31.58 | 0.65 |
| S.D. | 6.66 | 5.43 | 9.91 | 5.71 | 5.39 | 8.54 |
| Correlation to Grade (Pearson r) (df=108) | 0.09 | 0.03 | 0.04 | <0.01 | -0.13 | 0.08 |
| t-test of Pearson r (t-value) (df=108) | 0.94 | 0.34 | 0.44 | -0.03 | -1.36 | 0.83 |
| t-test of Pearson r (p-value) (df=108) | 0.35 | 0.73 | 0.66 | 0.98 | 0.18 | 0.41 |

A single sample t-test showed that AC-CE scores differed significantly from zero, $t(109)= 16.19$, $p= <0.001$. However, AE-RO scores did not differ significantly from zero according to the single sample t-test, $t(109)= 0.80$, $p= 0.42$.

**Differences in the Modified Kolb LSI Data between Males and Females in CHEM 2P20**

Of the 140 students who participated in the research, 69 were females and 70 were males, and one person did not provide gender information. Of the 140 students, 10 students did not receive a grade in the course, 14 did not complete the Kolb LSI correctly or completely, 5 both didn't complete the Kolb LSI correctly or completely and did not receive a final grade, and 1 student's gender was unknown. Of the 110 students who completed the modified Kolb LSI, received a final grade in CHEM 2P20, and whose gender was known, 55 were males and 55 were females.

Analysis of the Kolb LSI data showed that for both males and females there was no statistically significant correlation of any of the dimensions of AC, CE, AC-CE, AE, RO, or AE-RO with grade achieved in CHEM 2P20 (Table 26). Statistically significant differences were found between males and females on AC scores with males reporting higher AC scores, $t(108)=2.44$, $p=0.02$, and males also scoring higher AC-CE scores than females, $t(108)=2.00$, $p=<0.050$, (0.048).

Table 26. Modified Kolb LSI scores in CHEM 2P20 for Males and Females

| CHEM 2P20 | | Total AC | Total CE | AC-CE | Total AE | Total RO | AE-RO |
|---|---|---|---|---|---|---|---|
| Females (n=55) | Mean | 34.13 | 20.69 | 13.44 | 32.84 | 32.36 | 0.47 |
| | S.D. | 5.85 | 6.37 | 9.87 | 5.51 | 5.17 | 7.88 |
| | Correlation to 2P20 course Grade ( r ) (df=53) | 0.07 | 0.04 | 0.02 | 0.07 | -0.21 | 0.19 |
| | t-test of Pearson r (t-value) (df=53) | 0.52 | 0.30 | 0.11 | 0.51 | -1.56 | 1.38 |
| | t-test of Pearson r (p-value) (df=53) | 0.61 | 0.77 | 0.91 | 0.61 | 0.12 | 0.17 |
| Males (n=55) | Average | 37.16 | 20.00 | 17.16 | 31.64 | 30.80 | 0.84 |
| | S.D. | 7.12 | 4.32 | 9.68 | 5.89 | 5.54 | 9.23 |
| | Correlation to 2P20 course Grade ( r ) (df=53) | 0.10 | 0.03 | 0.06 | -0.07 | -0.04 | -0.02 |
| | t-test of Pearson r (t-value) (df=53) | 0.75 | 0.18 | 0.47 | -0.54 | -0.29 | -0.17 |
| | t-test of Pearson r (p-value) (df=53) | 0.46 | 0.86 | 0.61 | 0.59 | 0.77 | 0.87 |
| t-test between males' and females' scores | t value (df=108) | -2.44 | 0.67 | -2.00 | 1.10 | 1.53 | -0.22 |
| t-test between males' and females' scores | p value (df=108) | 0.02* | 0.50 | 0.05* | 0.27 | 0.13 | 0.83 |
| Effect Size | Cohen's d (df=108) | 0.47 | | 0.39 | | | |

*Note.* *p < 0.05

For the males, the AC-CE is significantly different from zero, $t(54) = 13.15$, $p<0.0001$, but AE-RO, $t(54) = 0.67$, $p=0.25$ is not significantly different from zero. For the females, the AC-CE is significantly different from zero, $t(54) = 10.10$, $p<0.0001$, but AE-RO, $t(54) = 0.45$, $p=0.33$ is not significantly different from zero. Figure 24 shows the Learning Styles from the modified Kolb Learning Styles Inventory for all sections of CHEM 2P20 (Organic Chemistry) separated by sex.

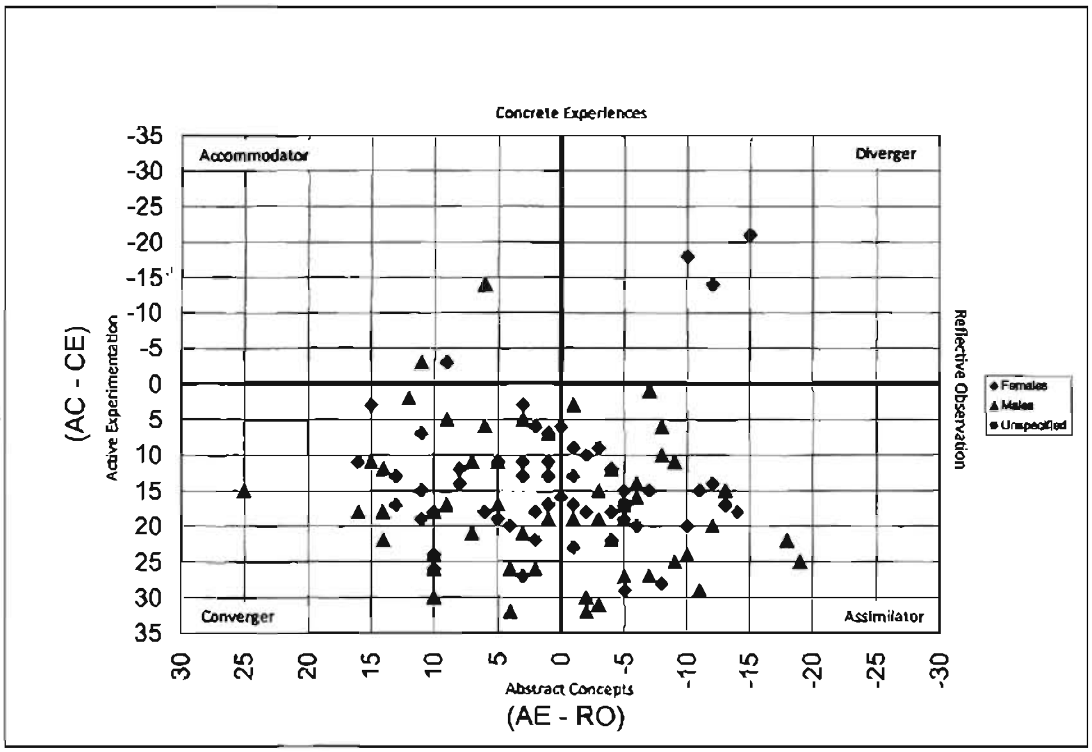


Figure 24. Kolb learning styles of the CHEM 2P20 class sorted by sex.

## CAEQ Attitude Data for CHEM 2P20

Of the 140 students who participated in the research while taking CHEM 2P20, eleven did not receive a grade, five neither received a grade nor completed the attitude questionnaire, and three received a grade but did not complete the attitude questionnaire. Therefore, CAEQ attitude questionnaire data and final course grades from 121 students were available.

Data from the CHEM 2P20 class are presented in Table 27. Overall attitude, as well as each of the attitude subscales, was found to be significantly different from zero (positive). There were no statistically significant correlations between final course grade achieved in CHEM 2P20 and the following: overall attitude, attitude regarding chemists, attitude regarding Chemistry research, attitude regarding leisure interest in Chemistry, nor attitude regarding Chemistry jobs.

Table 27. CAEQ Class Attitudinal Data for CHEM 2P20 and Correlation to Course Grade

| CHEM 2P20 Class Data | Overall Attitude | Attitude regarding Chemists | Attitude regarding Chemistry Research | Attitude regarding Leisure Interest | Attitude regarding Chemistry Jobs |
|---|---|---|---|---|---|
| Mean (n=121) | 1.17 | 0.94 | 2.09 | 0.68 | 1.24 |
| S.D. (n=121) | 0.64 | 0.82 | 0.88 | 1.12 | 0.93 |
| Correlation to Grade (df=119) | 0.07 | 0.04 | 0.07 | 0.09 | 0.02 |
| t-test of Pearson r (t-value) (df=119) | 0.78 | 0.42 | 0.74 | 0.93 | 0.24 |
| t-test of Pearson r (p value) (df=119) | 0.44 | 0.68 | 0.46 | 0.35 | 0.81 |
| One sample t-test (difference from zero) | | | | | |
| t value (df=120) | 20.05 | 12.64 | 26.18 | 6.72 | 14.60 |
| p value (df=120) | <.0001* | <.0001* | <.0001* | <.0001* | <.0001* |

*Note.* $*p < 0.05$

*Note.* Attitudes scale ranges from -3 to +3 with negative values denoting negative attitudes and positive values denoting positive attitudes.

**Differences in Attitude between Males and Females in CHEM 2P20**

Of the 140 students who participated in the research while taking CHEM 2P20, eleven did not receive a grade, five neither received a grade nor completed the attitude questionnaire, and three received a grade but did not complete the attitude questionnaire. Therefore, CAEQ attitude questionnaire data and final course grades from 121 students (59 females and 62 males) are presented in Table 28. For the females, there were no statistically significant correlations between overall CAEQ attitude scores and final course grade in CHEM 2P20 nor any significant correlations between final course grade and any of the CAEQ attitude subscales. For males, statistically significant correlations were found between overall CAEQ attitude and final course grade in CHEM 2P20 ($p=0.01$) as well as between attitude towards leisure interest in Chemistry and final course grade in CHEM 2P20 ($p<0.01$). There were no statistically significant differences between males and females in either overall CAEQ attitude or any of the CAEQ attitude subscales.

Table 28. Differences between Males and Females in CHEM 2P20 in Attitude Means as Measured by the CAEQ

| CHEM 2P20 | | Overall Attitude | Attitude Regarding Chemists | Attitude Regarding Chemistry Research | Attitude Regarding Leisure Interest | Attitude Regarding Chemistry Jobs |
|---|---|---|---|---|---|---|
| Females | Mean | 1.14 | 1.01 | 1.98 | 0.49 | 1.23 |
| (n=59) | S.D. | 0.64 | 0.83 | 0.95 | 1.07 | 0.96 |
| (df=57) | Correlation to Course Grade ( r ) | -0.16 | -0.14 | 0.03 | -0.23 | -0.07 |
| | t-test of Pearson r (t value) | -1.21 | -1.05 | 0.19 | -1.79 | -0.50 |
| | t-test of Pearson r (p value) | 0.23 | 0.30 | 0.85 | 0.08 | 0.62 |
| Males | Mean | 1.21 | 0.90 | 2.20 | 0.88 | 1.26 |
| (n=62) | S.D. | 0.64 | 0.81 | 0.79 | 1.14 | 0.91 |
| (df=60) | Correlation to Course Grade ( r ) | 0.33 | 0.24 | 0.13 | 0.40 | 0.13 |
| | t-test of Pearson r (t value) | 2.69 | 1.93 | 1.04 | 3.37 | 1.05 |
| | t-test of Pearson r (p value) | 0.01* | 0.06 | 0.30 | <0.01* | 0.30 |
| t-test between males and females | t value | -0.58 | 0.78 | -1.36 | -1.92 | -0.14 |
| (df=119) | p value | 0.56 | 0.44 | 0.18 | 0.06 | 0.89 |

*Note.* *p< 0.05
*Note.* Attitudes scale ranges from -3 to +3 with negative values denoting negative attitudes and positive values denoting positive attitudes.

**CAEQ Class Confidence Data for CHEM 2P20**

Of the 140 students who participated in this research while taking CHEM 2P20, twelve did not complete the course to receive a grade, four did not receive a grade nor complete the confidence questionnaire, and five did receive a grade but did not complete the confidence questionnaire. Therefore, data regarding confidence and course achievement are available for 119 students and presented in Table 29. There was no statistically significant correlation between course grade in CHEM 2P20 and overall confidence, lab work confidence, formulas confidence, critical thinking confidence, and confidence regarding written answers. Confidence discussing Chemistry was found to be statistically correlated to course grade achieved in CHEM 2P20 (p=0.04).

Table 29. CHEM 2P20 CAEQ Class Confidence Data and Correlation with Final Course Grade

| CHEM 2P20 Class Data | Overall Confidence | Confidence Discussing Chemistry | Lab Work Confidence | Formulas Confidence | Critical Thinking Confidence | Written Answers Confidence |
|---|---|---|---|---|---|---|
| Mean (n=119) | 0.65 | 0.31 | 0.58 | 0.75 | 0.69 | 0.92 |
| SD (n=119) | 0.50 | 0.64 | 0.68 | 0.69 | 0.52 | 0.67 |
| Correlation to Grade (df=117) | 0.07 | 0.19 | -0.06 | 0.00 | 0.12 | 0.04 |
| t-test of Pearson r (t-value) (df=117) | 0.76 | 2.07 | -0.70 | 0.04 | 1.36 | 0.46 |
| t-test of Pearson r (p-value) (df=117) | 0.45 | 0.04* | 0.49 | 0.97 | 0.18 | 0.65 |
| One sample t-tests (difference from zero) t value (df=118) p value (df=118) | 14.20<br><.0001* | 5.23<br><.0001* | 9.25<br><.0001* | 11.90<br><.0001* | 14.37<br><.0001* | 14.95<br><.0001* |

*Note.* *$p < 0.05$
*Note.* Scale ranges from -2 to +2 with negative values denoting lack of confidence and positive values denoting confidence.

**Differences in Confidence between Males and Females in CHEM 2P20**

Of the 140 students who participated in this research while taking CHEM 2P20, eleven did not complete the course to receive a grade, four did not complete the course and did not provide confidence data, and five completed the course to receive a grade but did not provide confidence data. Of the 120 for whom a grade and confidence data were available, 60 were females, 59 were males, and one student did not provide gender information. Therefore, data for the 60 females and 59 males are presented. For both the females and the males, there are no statistically significant correlations between final course grades and overall CAEQ confidence. Similarly, there were no statistically significant correlations for either males or females between final course grade in CHEM 2P20 and any of the CAEQ confidence subscales (Table 30).

Differences between males and females in terms of confidence using formulas approached statistical significance (p=0.06), while statistically significant differences were found between males and females in overall confidence, and the subscales confidence discussing Chemistry, lab work confidence, and critical thinking confidence. No statistically significant differences were found between males and females in terms of their confidence in written answers (Table 30).

Table 30. Males' and females' Confidence as Measured by the CAEQ for Students in CHEM 2P20 and Correlation with Final Course Grade

| CHEM 2P20 | Females (n=60) | | | | | Males (n=59) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Measure of Confidence | Mean | S.D. | Correlation to Grade (r) (df=58) | t-test of Pearson r (t-value) (df=58) | t-test of Pearson r (pvalue) (df=58) | Mean | S.D. | Correlation to Grade (r) (df=57) | t-test of Pearson r (t value) (df=57) | t-test of Pearson r (p value) (df=57) | t-test between males and females t value (df=117) | t-test between males and females p value (df=117) | Effect Size Cohen's d |
| Overall Average | 0.53 | 0.45 | 0.03 | 0.23 | 0.82 | 0.77 | 0.52 | 0.11 | 0.85 | 0.40 | -2.65 | 0.01* | -0.50 |
| Confidence Discussing Chemistry | 0.13 | 0.58 | 0.22 | 1.72 | 0.09 | 0.49 | 0.66 | 0.17 | 1.33 | 0.19 | -3.19 | <0.01* | -0.59 |
| Lab Work Confidence | 0.40 | 0.66 | -0.22 | -1.74 | 0.09 | 0.75 | 0.66 | 0.10 | 0.79 | 0.43 | -2.92 | <0.01* | -0.54 |
| Formulas Confidence | 0.63 | 0.63 | 0.02 | 0.14 | 0.89 | 0.87 | 0.73 | -0.01 | -0.09 | 0.93 | -1.92 | 0.06 | -0.36 |
| Critical Thinking Confidence | 0.57 | 0.50 | 0.20 | 1.57 | 0.12 | 0.81 | 0.52 | 0.05 | 0.38 | 0.71 | -2.58 | 0.01* | -0.48 |
| Confidence on Written Answers | 0.93 | 0.61 | -0.05 | -0.34 | 0.74 | 0.91 | 0.73 | 0.13 | 0.95 | 0.35 | 0.11 | 0.91 | 0.03 |

*Note.* *p < 0.05
*Note.* Confidence scale ranges from -2 to +2 with negative values denoting lack of confidence and positive values denoting confidence.

**CAEQ Experiences for CHEM 2P20**

CAEQ Experiences data was not collected from the Fall term of the CHEM 2P20 course as the students completed the questionnaires at the beginning of term and it was decided that students would not be able to accurately rate their lectures, labs, and tutorials after such a short time. Of the 140 students who participated in the research in CHEM 2P20, only 13 students both completed the course and provided CAEQ Experiences data. The data from those 13 students who took CHEM 2P20 in the Spring Term and completed the questionnaires in their final lectures are presented in Table 31. There was no statistically significant correlation between course grade in CHEM 2P20 and the students' experiences in either lectures, labs, or tutorials, or their overall experience in the course. Although the students reported positive experiences overall, in lecture, laboratory classes, and tutorials, these results must be interpreted with caution as this was a limited sample of students who competed the course. It is not known if students who might have reported less favourable experiences had already withdrawn from the course or might not have been present when the questionnaires were completed.

Table 31. CAEQ Experiences Data for CHEM 2P20 and Correlations to Course Grades

| CHEM 2P20 | Experiences in Lecture Classes | Experiences in Tutorial Classes | Experiences in Laboratory Classes | Overall Experiences |
|---|---|---|---|---|
| Mean (n=13, Spring Term) | 0.75 | 0.95 | 0.87 | 0.87 |
| S.D. | 0.47 | 0.38 | 0.36 | 0.33 |
| Correlation to Grade (df=11) | 0.04 | -0.13 | -0.38 | -0.18 |
| t-test of Pearson r t value (df=11) | 0.12 | -0.42 | -1.40 | -0.62 |
| t-test of Pearson r p value (df=11) | 0.91 | 0.68 | 0.19 | 0.55 |
| One sample t-test (difference from zero) t value (df=12) | 5.78 | 8.95 | 8.46 | 9.59 |
| p value (df=12) | <0.0001* | <0.0001* | <0.0001* | <0.0001* |

*Note.* *$p < 0.05$
*Note.* Scale ranges from -3 to +3 with negative values denoting negative attitudes and positive values denoting positive attitudes.

**Pressure from Family to Succeed in CHEM 2P20**

Of the 140 students who participated in this research while taking CHEM 2P20 and who completed the demographic section of the questionnaire package, 16 did not complete the course to receive a final grade, and therefore, data from 124 students are presented. These 124 students reported a mean pressure to succeed of 3.37 with a standard deviation of 1.70. No statistically significant correlation was found between grade earned in CHEM 2P20 and self-reported pressure from family to succeed in this course, $t(122)= -1.61$, $p=0.11$.

Of the 124 students, 61 were females who reported a mean pressure of 3.41 with a standard deviation of 1.27. However, no statistically significant correlation was found for the females between pressure to succeed and CHEM 2P20 course grade achieved, t(59)= -0.85, p=0.40 (Table 32). The 63 males reported a mean pressure to succeed of 3.33 with a standard deviation of 1.81. Similarly, no statistically significant correlation was found for the males between CHEM 2P20 course grade and self-reported family pressure to succeed, t(61)=-1.42, p=0.16 (Table 32). There was no statistically significant difference between males and females with respect to self-reported pressure from family to succeed in CHEM 2P20, t(122)= 0.33, p=0.74.

Table 32. Self-Reported Pressure to Succeed for Males and Females in CHEM 2P20 and Correlation to Final Course Grade

| CHEM 2P20 | Males (n=63) | | Females (n=61) |
|---|---|---|---|
| Mean Pressure to Succeed | 3.33 | Mean Pressure to Succeed | 3.41 |
| S.D. | 1.81 | S.D. | 1.27 |
| Correlation to Grade ( r ) (df=61) | -0.18 | Correlation to Grade ( r ) (df=59) | -0.11 |
| t-test of Pearson r (t-value) (df=61) | -1.42 | t-test of Pearson r (t-value) (df=59) | -0.85 |
| t–test of Pearson r (p value) (df=61) | 0.16 | t–test of Pearson r (p value) (df=59) | 0.40 |

*Note.* Pressure to succeed data was rated from 1 to 5, with 1 being a low pressure to succeed, and 5 being a great deal of pressure to succeed.

There was no statistically significant correlation between self-reported pressure to succeed in CHEM 2P20 and final course grade for both FFS and NFFS (Table 33). As well, there was no statistically significant difference between self-reported pressure to succeed in CHEM 2P20 between FFS and NFFS, t(122)= 0.73, p=0.47.

Table 33. Self-Reported Pressure to Succeed for FFS versus NFFS in CHEM 2P20 and Correlation to Final Course Grade

| CHEM 2P20 | NFFS (n=86) | | FFS (n=38) |
|---|---|---|---|
| Mean Self-Reported Pressure to Succeed | 3.31 | Mean Self-Reported Pressure to Succeed | 3.50 |
| S.D. | 1.65 | S.D. | 1.82 |
| Correlation to Final Course Grade (df=84) | -0.10 | Correlation to Final Course Grade (df=36) | -0.21 |
| t-test of Pearson r t value (df=84) | -0.88 | t-test of Pearson r t value (df=36) | -1.3 |
| t-test of Pearson r p value (df=84) | 0.38 | t-test of Pearson r p value (df=36) | 0.20 |

*Note.* Pressure to succeed data was rated from 1 to 5, with 1 being a low pressure to succeed, and 5 being a great deal of pressure to succeed.

**Living Arrangements of CHEM 2P20 Students**

Of the 140 students who participated in the research, 16 did not complete the course to receive a final grade; data regarding living arrangements are presented for 124 students (Table 34).

Table 34. Living Arrangements and Final Course Grade in CHEM 2P20

| CHEM 2P20 | Family (n=62) | Off-campus (n=53) | Residence (n=9) |
|---|---|---|---|
| Mean Final Course Grade | 66.08% | 58.21% | 65.33% |
| Standard Deviation | 13.24% | 11.55% | 13.22% |

One-way Analysis of Variance found that there was a statistically significant difference among the course grades for students based on different living arrangements; F(2)=5.85, P=<0.01. Analysis with t-tests showed that the two groups that had a statistically significant difference in mean course grade in CHEM 2P20 were those who lived with family versus those who lived off-campus but not with family, t(113)=3.37, p<0.01 with a strong Cohen's effect size of 0.64 (Table 35).

Table 35. Living Arrangements of Students in CHEM 2P20 and Mean Course Grades

| Living Arrangements during academic year | Average Grade in CHEM 2P20 (%) | S.D. | t-tests | t-test t value | t-test p value | Effect Size (Cohen's d) |
|---|---|---|---|---|---|---|
| With family (n=62) | 66.08 | 13.24 | Family vs. Off-campus (df=113) | 3.37 | <0.01* | 0.64 |
| Off-campus, but not with family (n=53) | 58.21 | 11.55 | Off-campus vs. Residence (df=60) | -1.68 | 0.10 | |
| Residence (n=9) | 65.33 | 13.22 | Family vs. Residence (df=69) | 0.16 | 0.87 | |

*Note.* *p < 0.05

**Students who completed Questionnaires in both CHEM 1F92 and CHEM 2P20**

In total, 60 students completed at least part of each questionnaire package while in CHEM 1F92 and again later while in CHEM 2P20. Fifty-four students completed both courses to obtain grades. The mean course grade of the 54 students while in CHEM 1F92 was 74.46% with a standard deviation of 10.84%; the mean course grade of the 54 students while in CHEM 2P20 was 61.93% with a standard deviation of 12.64%. The Pearson r correlation coefficient for the correlation of grades was 0.59. The t-test of Pearson r showed that there was a statistically significant correlation of course grade in CHEM 1F92 to course grade in CHEM 2P20 for those 54 students, $t(52)= 5.24$, $p<0.0001$.

**Kolb Learning Styles Inventories**

Comparisons cannot be made between Kolb LSI scores in CHEM 1F92 to Kolb LSI scores in CHEM 2P20. While in CHEM 1F92, students were asked to complete the Kolb LSI with the specific instructions to think of situations involving the learning of Chemistry, while the questionnaires completed by students while in CHEM 2P20 asked the students to specifically think of a learning situation where they were learning Organic Chemistry. Students were given different instructions for the two administrations of the Kolb LSI, and therefore the Kolb LSI was measuring two different things: Chemistry and Organic Chemistry.

**Chemistry CHEM 2P42 Data Collected**

All thirty-nine students registered in CHEM 2P42 at the beginning of term participated in the research during their lab sessions. Of these 39 students, 15 did not complete the course to receive a grade. The mean course grade for the 24 students who completed the course was 63.33% with a standard deviation of 14.44%.

**Course Grades for Males and Females in CHEM 2P42**

Of the 24 students for whom final course grades in CHEM 2P42 were available, 16 were males and 8 were females. The mean grade for the males was 65.75% with a standard deviation of 14.63%; the mean grade for the females was 58.5% with a standard deviation of 13.65%. No statistically significant differences between the mean course grades was found, $t(22)= 1.17$, $p=0.25$.

**Course Grades for FFS and NFFS in CHEM 2P42**

Of the 24 students for whom final course grades in CHEM 2P42 were available, 8 were FFS and 16 were NFFS. The mean course grade for the FFS was 66.88% with a standard deviation of 15.51%; the mean course grade for the NFFS was 61.56% with a standard deviation of 14.05%. No statistically significant difference was found between mean course grades for these two groups; $t(22)=0.84$, $p=0.41$.

**CHEM 2P42 Modified Kolb Learning Styles Inventory Data**

Of the 39 students who participated in the research while taking CHEM 2P42, 12 did not complete the course to receive a grade, 3 both did not complete the course to receive a grade and did not complete the modified Kolb LSI completely and correctly, and 4 did not complete the modified Kolb LSI completely or correctly. The Learning Styles Inventory results of the twenty students who completed CHEM 2P42 to receive a grade and completed the modified Kolb LSI correctly are shown in Figure 25. Since two students' scores have AE-RO values of zero, they straddle two different learning styles. Therefore, mean course grades per quadrant cannot be calculated as these two students cannot be assigned to a given quadrant.

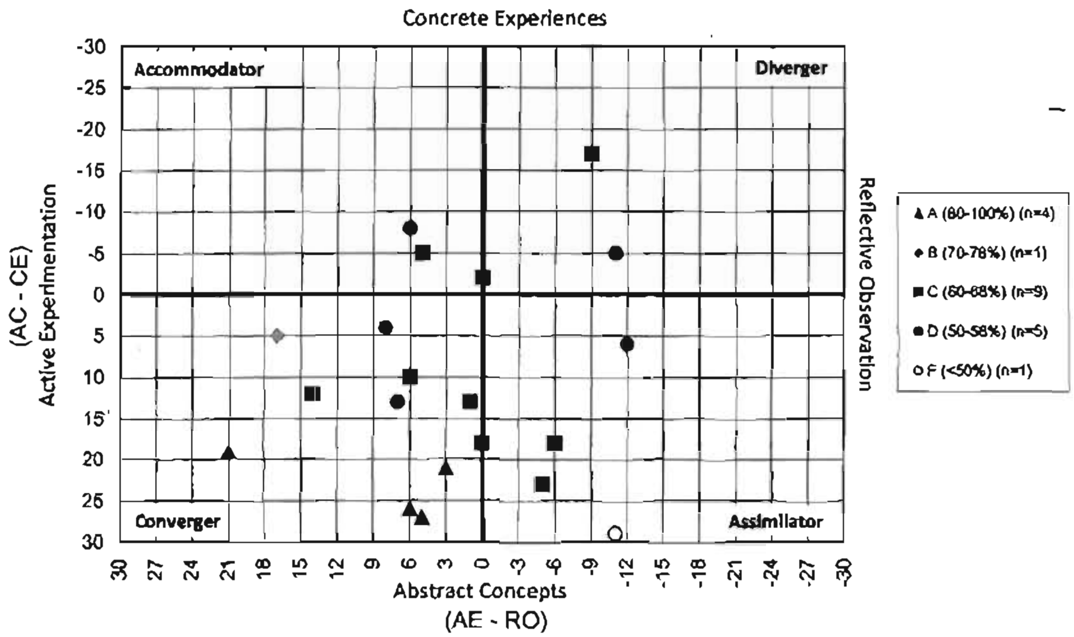


Figure 25. Modified Kolb LSI data for the CHEM 2P42 (Analytical Chemistry) course sorted by final course grade.

No statistically significant correlation was found between course grade in CHEM 2P42 and any of the dimensions of the Kolb LSI: AC, CE, AC-CE, AE, RO, and AE-RO (Table 36).

Table 36. Mean Kolb LSI Scores and Correlation to Grade Achieved in CHEM 2P42

| CHEM 2P42 (n=20) | Total AC | Total CE | AC-CE | Total AE | Total RO | AE-RO |
|---|---|---|---|---|---|---|
| Mean | 32.50 | 22.15 | 10.35 | 33.80 | 31.55 | 2.25 |
| S.D. | 7.81 | 7.49 | 12.87 | 7.08 | 5.21 | 9.27 |
| Correlation (df=18) | 0.30 | -0.25 | 0.33 | 0.23 | -0.39 | 0.39 |
| t-test of Pearson r t value (df=18) | 1.31 | -1.12 | 1.47 | 1.00 | -1.78 | 1.81 |
| t-test of Pearson r p value (df=18) | 0.21 | 0.28 | 0.16 | 0.33 | 0.09 | 0.09 |

*Note.* * $p<0.05$

One sample t-tests of AC-CE and AE-RO scores showed the AC-CE is significantly different from zero, $t(19) = 3.60$, $p<0.01$, but that AE-RO, $t(19) = 1.09$, $p=0.29$ is not significantly different from zero.

**CHEM 2P42 Kolb Learning Styles Inventory Data by Sex**

Of the 39 students who participated in the research, 7 did not complete the modified Kolb LSI completely or correctly. Of the 32 students who did complete the modified Kolb LSI correctly, 12 did not complete the course to receive a final grade, and therefore modified Kolb LSI data can only be correlated with the grades of 20 students (14 males and 6 females). Figure 26 shows the modified Kolb LSI data separated for males and females and the centroids of data for those who completed the course.

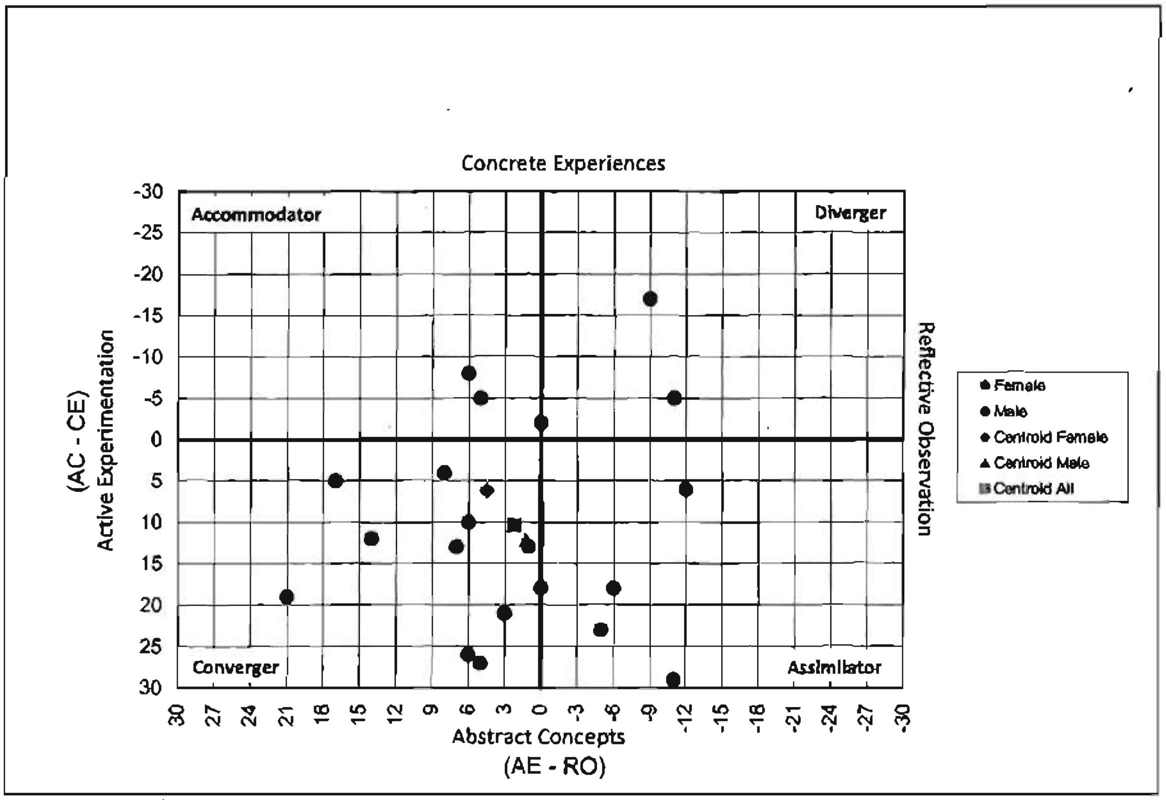


Figure 26. Modified Kolb Learning Styles Inventory data and centroids for the CHEM 2P42 Analytical Chemistry class sorted by sex.

No statistically significant differences were found between the males and females in CHEM 2P42 regarding the modified Kolb LSI data and final grade in CHEM 2P42 (Table 37). As well, no significant correlations were found between any of the Kolb LSI dimensions and grade obtained in CHEM 2P42 (Table 37).

Table 37. Comparison of LSI dimensions for Males and Females in CHEM 2P42

| | CHEM 2P42 | Total AC | Total CE | AC-CE | Total AE | Total RO | AE-RO |
|---|---|---|---|---|---|---|---|
| Males | Mean | 32.86 | 20.71 | 12.14 | 33.86 | 32.57 | 1.29 |
| (n=14) | Standard Deviation | 7.73 | 6.43 | 11.89 | 6.57 | 5.17 | 8.89 |
| | Correlation to Grade (df=12) | 0.32 | -0.39 | 0.42 | 0.31 | -0.40 | 0.46 |
| | t-test of Pearson r t value (df=12) | 1.19 | -1.47 | 1.61 | 1.15 | -1.50 | 1.81 |
| | t-test of Pearson r p value (df=12) | 0.26 | 0.17 | 0.13 | 0.27 | 0.16 | 0.10 |
| Females | Mean | 31.67 | 25.50 | 6.17 | 33.67 | 29.17 | 4.50 |
| (n=6) | Standard Deviation | 8.66 | 9.29 | 15.24 | 8.82 | 4.88 | 10.62 |
| | Correlation to Grade (df=4) | 0.22 | 0.05 | 0.09 | 0.03 | -0.54 | 0.27 |
| | t-test of Pearson r t value (df=4) | 0.44 | 0.11 | 0.18 | 0.05 | -1.27 | 0.56 |
| | t-test of Pearson r p value (df=4) | 0.68 | 0.92 | 0.87 | 0.96 | 0.27 | 0.61 |
| t-test between males and females | t value | -0.30 | 1.34 | -0.95 | -0.05 | -1.37 | 0.70 |
| (df=18) | p value | 0.77 | 0.20 | 0.35 | 0.96 | 0.19 | 0.49 |

*Note.* *$p < 0.05$

**Differences in Kolb LSI Data between FFS and NFFS**

Of the 39 students who participated in the research while taking CHEM 2P42, four did not complete the modified Kolb LSI, three did not complete the modified Kolb LSI and did not receive a final grade in the course, and twelve others did not complete the course to obtain a grade. Therefore, twenty students (8 FFS and 12 NFFS) both completed the modified Kolb LSI and obtained a final grade in the course.

No statistically significant correlations were found for FFS between any of the modified Kolb LSI scales and final course grade achieved in CHEM 2P42. However, for NFFS, statistically significant positive correlations were found between final course grade and AE score, t(10)= 2.70, p=0.02, and between AE-RO and final course grade achieved, t(10)=3.17, p=0.01. There were no statistically significant differences between FFS and NFFS with respect to their scores on any of the modified Kolb LSI scales (Table 38).

Table 38. Differences in Kolb LSI Data between FFS and NFFS and Correlations to Grade Achieved in CHEM 2P42

| CHEM 2P42 | | Total AC | Total CE | AC-CE | Total AE | Total RO | AE-RO |
|---|---|---|---|---|---|---|---|
| FFS | Mean | 32.38 | 25.13 | 7.25 | 32.50 | 30.00 | 2.50 |
| n=8 | SD | 9.59 | 9.03 | 16.22 | 6.95 | 3.55 | 6.14 |
| | Correlation to Grade | 0.56 | -0.36 | 0.53 | -0.23 | -0.14 | -0.18 |
| | T-test of Pearson r t value (df=6) | 1.65 | -0.95 | 1.54 | -0.57 | -0.34 | -0.44 |
| | p value | 0.15 | 0.38 | 0.17 | 0.59 | 0.75 | 0.68 |
| NFFS | Mean | 32.58 | 20.17 | 12.42 | 34.67 | 32.58 | 2.08 |
| n=12 | SD | 6.84 | 5.84 | 10.35 | 7.33 | 5.99 | 11.16 |
| | Correlation to Grade | 0.00 | -0.27 | 0.15 | 0.65 | -0.53 | 0.71 |
| | t-test of Pearson r t value (df=10) | -0.02 | -0.88 | 0.48 | 2.70 | -1.95 | 3.17 |
| | t-test of Pearson r p value (df=10) | 0.98 | 0.40 | 0.64 | 0.02* | 0.08 | 0.01* |
| | t-test between FFS and NFFS t value (df=18) | -0.06 | 1.50 | -0.87 | -0.66 | -1.09 | 0.10 |
| | t-test between FFS and NFFS p value (df=18) | 0.95 | 0.15 | 0.40 | 0.52 | 0.29 | 0.92 |

*Note.* *$p < 0.05$

## CAEQ Attitude Data for Students in CHEM 2P42

Of the 39 students who participated in this research, one student did not complete the Attitude section of the CAEQ, and 15 others did not obtain a final course grade in CHEM

2P42. Therefore data from the 23 students who completed both the Attitude section of the CAEQ and obtained a final course grade are presented.

Mean overall CAEQ attitude values were all positive values, as were mean values for all CAEQ attitude subscales. Overall attitude, as well as each of the attitude subscales, was found to be significantly different from zero (positive). Statistically significant correlations were not found to exist between the overall attitude as measured by the CAEQ with final grade achieved in CHEM 2P42, nor any of the CAEQ attitude subscales with final grade achieved (Table 39).

Table 39. Mean CAEQ Attitudinal Class Data for CHEM 2P42, Correlated with Final Course Grade Achieved

| CHEM 2P42 | Overall Average | Chemists Average | Chemistry Research Average | Leisure Average | Chemistry Jobs Average |
|---|---|---|---|---|---|
| Mean Grade (n=23) | 1.06 | 0.91 | 1.62 | 0.59 | 1.27 |
| S.D. (n=23) | 0.65 | 0.81 | 1.20 | 1.16 | 1.01 |
| Correlation to Grade (df=21) | 0.12 | 0.09 | 0.22 | 0.15 | -0.14 |
| t-test of Pearson r t value (df=21) | 0.54 | 0.40 | 1.04 | 0.67 | -0.64 |
| t-test of Pearson r p value (df=21) | 0.59 | 0.69 | 0.31 | 0.51 | 0.53 |
| One sample t-test (difference from zero) t value (df=22) p value (df=22) | 7.87 <.0001* | 5.40 <.0001* | 6.48 <.0001* | 2.42 0.02* | 6.01 <.0001* |

*Note.* *p < 0.05
*Note.* Scale ranges from -3 to +3 with negative values denoting negative attitudes and positive values denoting positive attitudes.

**Differences in Attitude between Males and Females in CHEM 2P42**

Of the 39 students who participated in this research, one student did not complete the Attitude section of the CAEQ, and 15 did not obtain a final course grade in CHEM 2P42. Therefore data from the 23 students (16 males and 7 females) who completed both the Attitude questionnaire and obtained a final grade are presented. No statistically significant correlations were found to exist between overall attitude, or any of the attitude subscales, with final course grade. This was true for both males and females. As well, no statistically significant differences were found between males and females regarding their overall attitude nor regarding attitude for each subscale (Table 40).

Table 40. Mean CAEQ Attitudinal Data for Males and Females in CHEM 2P42, Correlated with Final Course Grade Achieved

| CHEM 2P42 | | Overall Average | Chemists Average | Chemistry Research Average | Leisure Average | Chemistry Jobs Average |
|---|---|---|---|---|---|---|
| Males | Mean | 1.03 | 0.81 | 1.52 | 0.72 | 1.28 |
| (n=16) | S.D. | 0.75 | 0.90 | 1.24 | 1.30 | 1.14 |
| | Correlation to Grade | 0.09 | -0.01 | 0.19 | 0.25 | -0.11 |
| | t-test of Pearson r t- value (df=14) | 0.35 | -0.03 | 0.72 | 0.96 | -0.41 |
| | t-test of Pearson r p- value (df=14) | 0.73 | 0.98 | 0.48 | 0.35 | 0.69 |
| Females | Mean | 1.15 | 1.16 | 1.86 | 0.29 | 1.26 |
| (n=7) | S.D. | 0.36 | 0.55 | 1.15 | 0.77 | 0.73 |
| | Correlation to Grade | 0.41 | 0.73 | 0.44 | -0.45 | -0.29 |
| | t-test of Pearson r t-value (df=5) | 1.00 | 2.42 | 1.09 | -1.13 | -0.68 |
| | t-test of Pearson r p-value (df=5) | 0.36 | 0.06 | 0.33 | 0.31 | 0.53 |
| t-test of males to females (df=21) | t value | 0.41 | 0.96 | 0.62 | -0.81 | -0.04 |
| t-test of males to females (df=21) | p value | 0.69 | 0.35 | 0.54 | 0.43 | 0.97 |

*Note.* Scale ranges from -3 to +3 with negative values denoting negative attitudes and positive values denoting positive attitudes.

**CAEQ Confidence Data for Students Taking CHEM 2P42**

Of the 39 students who participated in this research, one student did not complete the confidence section of the CAEQ and 15 other students did not complete the course to achieve a final grade. Therefore, data from 23 students who completed both the CAEQ confidence questionnaire and completed CHEM 2P42 to achieve a final grade are presented.

Statistically significant positive correlations were found to exist between overall confidence and final grade achieved in CHEM 2P42, $t(21)=3.08$, $p=0.01$. As well, statistically significant positive correlations were found between final course grade in CHEM 2P42 and the following: confidence discussing Chemistry, $t(21)=2.94$, $p=0.01$; lab work confidence, $t(21)= 2.16$, $p=0.04$; confidence using formulas, $t(21)=2.74$, $p=0.01$; and critical thinking confidence, $t(21)= 2.44$, $p=0.02$. Confidence of providing written answers approaches statistical significance at $t(21)=1.98$, $p=0.06$ (Table 41).

Table 41. Mean CAEQ Confidence Class Data for CHEM 2P42, Correlated with Final Course Grade

| CHEM 2P42 | Overall Confidence | Confidence Discussing Chemistry | Lab Work Confidence | Confidence Using Formulas | Critical Thinking Confidence | Written Answers Confidence |
|---|---|---|---|---|---|---|
| Mean (n=23) | 0.78 | 0.39 | 0.87 | 0.98 | 0.87 | 0.82 |
| S.D. | 0.64 | 0.86 | 0.67 | 0.75 | 0.73 | 0.80 |
| Correlation to Grade (df=21) | 0.56 | 0.54 | 0.43 | 0.51 | 0.47 | 0.40 |
| t-test of Pearson r t value (df=21) | 3.08 | 2.94 | 2.16 | 2.74 | 2.44 | 1.98 |
| t-test of Pearson r p value (df=21) | 0.01* | 0.01* | 0.04* | 0.01* | 0.02* | 0.06 |
| One sample t-tests (difference from zero) t value (df=22) p value (df=22) | 5.85 <.0001* | 2.19 0.04* | 6.22 <.0001* | 6.26 <.0001* | 5.71 <.0001* | 4.90 <.0001* |

*Note.* *$p < 0.05$

*Note.* Scale ranges from -2 to +2 with negative values denoting lack of confidence and positive values denoting confidence.

**Differences in Confidence between Males and Females in CHEM 2P42**

Of the 39 students who participated in this research, one student did not complete the confidence section of the CAEQ and 15 other students did not complete the course to achieve a final grade. Therefore, data from 23 students (16 males and 7 females) who completed both the CAEQ confidence questionnaire and completed CHEM 2P42 to achieve a final grade are presented.

For the 16 males, neither overall confidence nor any of the confidence subscales were found to be statistically significantly correlated to final grade achieved in CHEM 2P42. However, for the 7 females, statistically significant correlations were found to exist between final course grade achieved and: overall confidence, $p(5)=0.03$; confidence discussing Chemistry, $p(5)= 0.01$; and confidence in lab work, $p(5)= 0.02$. The correlation between final grade achieved in CHEM 2P42 and confidence in written answers for the females approached statistical significance, $p(5)= 0.06$. There were no statistically significant differences between the males and females in their overall mean confidence, nor in any of the subscales (Table 42).

Table 42. Mean CAEQ Confidence Data for Males and Females in CHEM 2P42, Correlated with Final Course Grade Achieved

| CHEM 2P42 | | Overall Confidence | Confidence Discussing Chemistry | Lab Work Confidence | Confidence Using Formulas | Critical Thinking Confidence | Written Answers Confidence |
|---|---|---|---|---|---|---|---|
| Males | Mean | 0.88 | 0.56 | 1.03 | 1.03 | 0.95 | 0.81 |
| n=16 | S.D. | 0.51 | 0.76 | 0.60 | 0.59 | 0.64 | 0.74 |
| | Correlation to Grade (df=14) | 0.40 | 0.34 | 0.19 | 0.39 | 0.38 | 0.24 |
| | t-test of Pearson r t-value (df=14) | 1.63 | 1.36 | 0.72 | 1.60 | 1.53 | 0.93 |
| | t-test of Pearson r p-value (df=14) | 0.13 | 0.20 | 0.48 | 0.13 | 0.15 | 0.37 |
| Females | Mean | 0.57 | 0.00 | 0.50 | 0.86 | 0.68 | 0.82 |
| n=7 | S.D. | 0.89 | 1.00 | 0.72 | 1.08 | 0.93 | 0.99 |
| | Correlation to Grade (df=5) | 0.79 | 0.86 | 0.82 | 0.72 | 0.60 | 0.74 |
| | t-test of Pearson r t-value (df=5) | 2.92 | 3.84 | 3.17 | 2.32 | 1.69 | 2.43 |
| | t-test of Pearson r p-value (df=5) | 0.03* | 0.01* | 0.02* | 0.07 | 0.15 | 0.06 |
| t-test of males to females | t-value (df=21) | -1.05 | -1.49 | -1.84 | -0.50 | -0.82 | 0.02 |
| t-test of males to females | p-value (df=21) | 0.31 | 0.15 | 0.08 | 0.62 | 0.42 | 0.98 |

*Note.* *$p < 0.05$
*Note.* Scale ranges from -2 to +2 with negative values denoting lack of confidence and positive values denoting confidence.

**Differences in Confidence between FFS and NFFS in CHEM 2P42**

Of the 39 students who participated in the research, one did not complete the confidence section of the CAEQ and fifteen others did not complete the course to receive a final course grade. Therefore confidence data and final grades in CHEM 2P42 for 23 students (8 FFS and 15 NFFS) who completed the confidence section of the CAEQ and obtained a final grade in the course are presented.

For the FFS, there was a statistically significant positive correlation between final course grade in CHEM 2P42 and confidence in discussing Chemistry, $t(6)=2.92$, $p=0.03$. For the NFFS, there was a statistically significant positive correlation between final course grade in CHEM 2P42 and overall confidence, $t(13)=2.30$, $p=0.04$, and a statistically significant correlation between final course grade and confidence using formulas, $t(13)= 2.80$, $p=0.02$. There were no statistically significant differences between FFS and NFFS in either their overall confidence or in any of the subscales (Table 43).

Table 43. Differences in CAEQ Confidence Measures between FFS and NFFS and Correlations to Final Course Grade in CHEM 2P42

| CHEM 2P42 | | Overall Confidence | Confidence Discussing Chemistry | Lab Work Confidence | Confidence Using Formulas | Critical Thinking Confidence | Written Answers Confidence |
|---|---|---|---|---|---|---|---|
| FFS | Mean (n=8) | 0.86 | 0.31 | 0.78 | 1.06 | 1.00 | 1.13 |
| | S.D. | 0.49 | 0.78 | 0.51 | 0.61 | 0.65 | 0.44 |
| | Correlation to Grade | 0.64 | 0.77 | 0.58 | 0.27 | 0.53 | 0.38 |
| | t-test of Pearson r t value (df=6) | 2.03 | 2.92 | 1.75 | 0.70 | 1.52 | 1.01 |
| | t-test of Pearson r p value (df=6) | 0.09 | 0.03* | 0.13 | 0.51 | 0.18 | 0.35 |
| NFFS | Mean (n=15) | 0.75 | 0.43 | 0.92 | 0.93 | 0.80 | 0.65 |
| | S.D. | 0.72 | 0.92 | 0.75 | 0.83 | 0.78 | 0.91 |
| | Correlation to Grade | 0.54 | 0.47 | 0.42 | 0.61 | 0.43 | 0.40 |
| | t-test of Pearson r t value (df=13) | 2.30 | 1.91 | 1.64 | 2.80 | 1.73 | 1.56 |
| | t-test of Pearson r p value (df=13) | 0.04* | 0.08 | 0.12 | 0.02* | 0.11 | 0.14 |
| t-test between FFS and NFFS | t value (df=21) | 0.38 | -0.32 | -0.45 | 0.39 | 0.62 | 1.39 |
| | p value (df=21) | 0.71 | 0.75 | 0.66 | 0.70 | 0.54 | 0.18 |

*Note.* *$p < 0.05$

*Note.* Scale ranges from -2 to +2 with negative values denoting lack of confidence and positive values denoting confidence.

**CAEQ Experiences for CHEM 2P42**

CAEQ Experiences data was not collected from the CHEM 2P42 students as the students completed the questionnaires at the beginning of term and it was decided that the students would not be able to accurately rate their lectures, labs, and tutorials after such a short time.

**Pressure to Succeed CHEM 2P42 Class Data**

Of the 39 students who participated in the research while taking CHEM 2P42, 15 did not complete the course to receive a final grade, and therefore data regarding pressure to succeed are presented for 24 students. Students were asked to self-report on a Likert scale from 1-5 how much pressure they experienced from their families to be successful in CHEM 2P42 with 1 corresponding to no pressure and 5 corresponding to a great deal of pressure. The 24 students reported a mean pressure to succeed of 3.58 with a standard deviation of 1.35. The Pearson r correlation was found to be -0.35, however this was not statistically significant, $t(22)=-1.71$, $p=0.10$.

**Pressure to Succeed for Males and Females in CHEM 2P42**

Students were asked to self-report on a Likert scale from 1-5 how much pressure they experienced from their families to be successful in CHEM 2P42 with 1 corresponding to no pressure and 5 corresponding to a great deal of pressure. Of the 24 students who completed the course and provided data on pressure to succeed, 16 were males and 8 were females. Males reported a mean pressure to succeed of 3.31 with a standard deviation of 1.40 while females reported a mean pressure to succeed of 4.13 with a standard deviation of 1.13 (Table 44.) There was no statistically significant correlation of pressure to succeed with grade achieved for females t(6)= -0.88, p=0.41 and similarly for the males, t(14) = -1.09, p=0.29 . A t-test showed that there was no significant difference between pressure to succeed for males and pressure to succeed for females, t(22)= 0.81, p=0.17.

Table 44. Self-Reported Pressure to Succeed for Males and Females in CHEM 2P42 and Correlation to Final Course Grade

| CHEM 1F92 | Males (n=16) | | Females (n=8) |
|---|---|---|---|
| Mean Pressure to Succeed | 3.31 | Mean Pressure to Succeed | 4.13 |
| S.D. | 1.40 | S.D. | 1.13 |
| Correlation to Grade (df=14) | -0.28 | Correlation to Grade (df=6) | -0.34 |
| t-test of Pearson r (t-value) (df=14) | -1.09 | t-test of Pearson r (t-value) (df=6) | -0.88 |
| t–test of Pearson r (p value) (df=14) | 0.29 | t–test of Pearson r (p value) (df=6) | 0.41 |

*Note.* Pressure to succeed scale ranges from 1 to 5 with 1 signifying low pressure to succeed and 5 signifying a great deal of pressure to succeed.

**Differences in Pressure to Succeed between FFS and NFFS in CHEM 2P42**

Students were asked to self-report on a Likert scale from 1-5 how much pressure they experienced from their families to be successful in CHEM 2P42 with 1 corresponding to no pressure and 5 corresponding to a great deal of pressure. Of the 24 students who completed the course and reported pressure to succeed data, 8 were FFS and 16 were NFFS. No statistically significant differences were found between FFS who reported a mean pressure to succeed of 3.50 with a standard deviation of 1.51 as compared to NFFS who reported a mean pressure to succeed score of 3.63 with a standard deviation of 1.31, t(22)= -0.21, p=0.84. Pressure to succeed was not correlated to course grade achieved for NFFS, t(14)= -0.23, p=0.82, however pressure to succeed in CHEM 2P42 was found to be negatively correlated (-0.81) with course grade in CHEM 2P42 for FFS, t(6)= -3.43, p=0.01 (Table 45).

Table 45. Self-Reported Pressure to Succeed for FFS and NFFS in CHEM 2P42 and Correlation to Final Course Grade

| CHEM 2P42 | NFFS (n=16) | | FFS (n=8) |
|---|---|---|---|
| Mean Self-Reported Pressure to Succeed | 3.63 | Mean Self-Reported Pressure to Succeed | 3.50 |
| S.D. | 1.31 | S.D. | 1.51 |
| Correlation to Final Course Grade (df=14) | -0.06 | Correlation to Final Course Grade (df=6) | -0.81 |
| t-test of Pearson r t value (df=14) | -0.23 | t-test of Pearson r t value (df=6) | -3.43 |
| t-test of Pearson r p value (df=14) | 0.82 | t-test of Pearson r p value (df=6) | 0.01* |

*Note.* Pressure to succeed scale ranges from 1 to 5 with 1 signifying low pressure to succeed and 5 signifying a great deal of pressure to succeed.

**Living Arrangements of CHEM 2P42 Students**

Of the 39 students who participated in the research, 15 did not complete the course to receive a final grade; data regarding living arrangements are presented for 24 students (Table 46). There was no statistically significant difference between the final course grades of those who lived with family as compared with those students who lived off-campus, t(22)= 0.61, p=0.55. There were no students who participated in this research in CHEM 2P42 who completed the course, provided living arrangements data, and lived in residence.

Table 46. Living Arrangements and Final Course Grade in CHEM 2P42

| | 2P42 Living Arrangements | | |
|---|---|---|---|
| | Family | Off Campus. | Residence |
| Number of Students | 12 | 12 | 0 |
| Mean Course Grade | 65.17% | 61.50% | NA |
| S.D. | 16.40% | 12.63% | NA |

**Comparisons between CHEM 1F92 and CHEM 2P20 and between CHEM 2P20 and CHEM 2P42**

Comparisons were not done between CHEM 1F92 and CHEM 2P42 due to the small sample size of CHEM 2P42 (24 students). Similarly, comparisons were not done between CHEM 2P20 and CHEM 2P42 due to the small sample size of CHEM 2P42.

# DISCUSSION

## Final Course Grades in CHEM 1P00, CHEM 1F92, CHEM 2P20, and CHEM 2P42

Final course grades in CHEM 1F92 were found to be significantly correlated with final course grades in CHEM 2P20 for the 60 students who participated in this research twice, first while taking CHEM 1F92 and then again while in CHEM 2P20. Similar comparisons were not done between CHEM 1F92 and CHEM 2P42 due to the small sample size who completed the questionnaires in CHEM 1F92, then completed the questionnaires again in CHEM 2P42, and completed both courses to obtain final course grades (12 students). As well, comparisons were not done between CHEM 2P20 and CHEM 2P42 due to the small number of students who completed questionnaires in both CHEM 2P20 and CHEM 2P42 and completed both courses to obtain a final course grade (10 students).

In CHEM 1P00, CHEM 2P20, and CHEM 2P42, there were no statistically significant differences between males and females in their final course grades. In CHEM 1F92, females' mean final course grade was significantly higher than the mean final course grade of males. However, females were also significantly more likely to withdraw from the course, while males were more likely to fail which might partially explain the difference in final course grades. While previous research such as that of Grayson (1997) found that FG students tended to score lower than their counterparts, this research did not find any statistically significant difference in mean final course grades achieved between FFS and NFFS for any of the four courses studied (CHEM 1P00, CHEM 1F92, CHEM 2P20, and CHEM 2P42).

## Kolb Learning Style Inventory Data

In all four of the courses studied (CHEM 1P00, CHEM 1F92, CHEM 2P20, and CHEM 2P42), single sample t-tests showed a statistically significant difference from zero for AC-CE scores indicating that in each group AC was favoured over CE. In each of the four courses studied, AE-RO scores were not shown to be statistically significantly different from zero in single sample t-tests, indicating that neither AE nor RO was favoured. The centroid for the class data for each of the four courses falls in the Converger quadrant. These results are similar to the work of Smedley (1987), who found that the centroid of the Kolb LSI data of 441 ACS chemists was in the Converger quadrant with a mean AC-CE score of 5.41, and a mean AE-RO score of 4.46. The results of this research project also support the work of Kolb (1984) who categorized Chemistry majors typically as Assimilators, and those in the natural sciences (many of whom would be taking first and second year Chemistry courses) as either Convergers or Assimilators, both favouring AC over CE.

In both CHEM 1P00 and CHEM 1F92, AC scores were significantly positively correlated with course grade, and AC-CE was positively correlated to course grade in CHEM 1F92. As well, RO was negatively correlated to course grade in CHEM 1P00 and CE was negatively correlated to course grade in CHEM 1F92. No correlations, either positive or negative were found between LSI dimensions and final course grades for CHEM 2P20 and CHEM 2P42.

## Differences between Males vs. Females with Respect to the Kolb Learning Styles Inventory

In CHEM 1P00 and CHEM 2P20, males' scores on AC were significantly higher than those of females. Males in CHEM 2P20 also scored higher in AC-CE than females. This is similar to the work of Kolb and Kolb (2005) who found that males scored significantly higher in AC-CE than females. In CHEM 1F92, males were also found to have higher CE scores than females, while females scored significantly higher in the RO dimension. However, this research is in contrast to the results by Smedley (1987) which showed that among 441 ACS chemists, there was no difference in learning styles between males and females. However, Smedley's (1987) research was of a group of practicing chemists, while Kolb and Kolb's (2005) study was of a normative sample of individuals with a variety of backgrounds.

No differences in Kolb LSI dimension scores were found between males and females in CHEM 2P42 which supports Smedley's (1987) study. The CHEM 2P42 students are likely Chemistry majors, or combined majors, and therefore perhaps more similar to Smedley's sample of chemists, as compared to Kolb and Kolb's (2005) normative sample.

## Incorporating Kolb's Experiential Learning Theory into Lectures

In each of the four courses studied, CHEM 1P00, CHEM 1F92, CHEM 2P20, and CHEM 2P42, single sample t-tests showed that AC-CE scores were significantly different from zero and favoured the AC dimension. As well, it was found that AC was significantly correlated to final course grades in CHEM 1P00, while AC and AC-CE scores were significantly positively correlated with course grade in CHEM 1F92. While the concepts in

Chemistry are abstract, students must also be able to understand the practical application of the ideas in everyday life. By beginning at the concrete and working towards the abstract, those who prefer CE would be able to understand, without diminishing the quality of instruction for those who prefer to learn through AC.

For students who prefer RO to AE, it is beneficial for instructors to do demonstrations in lecture (or laboratories) whenever possible, or provide links to on-line resources such as video clips of reactions. Students who prefer RO would obtain information in their preferred mode, while simultaneously helping all students establish the connections between Chemistry at the sub-micro and representative levels to the macro level. Students also tend to greatly enjoy demonstrations, which would likely improve their attitudes about their Chemistry courses.

By providing real-life applications in lecture of concepts that are being studied, Divergers will understand the relevance, which is essential to their learning. Incorporating the use of clickers and group discussion in lecture would also aid the Divergers, who value working with others. By giving time for groups to discuss concepts, the Assimilators, who appreciate being given the time to process ideas, will be able to do so. Convergers will enjoy the opportunity to apply the concepts learned to problem solving in the clicker questions, and Accommodators can be shown or prompted to realize the other possibilities of the techniques or theories tested.

## Incorporating Kolb's Experiential Learning Theory into Labs

Labs provide hands-on experiences for those who prefer AE. They also reinforce the concepts of lecture by making the concepts concrete (CE) and allow for reflection of the problem being studied (RO). The opportunity to design experiments (AC) not only empowers students to own their learning, but trains them to design their own experiments for their Honours projects, graduate work, and future employment.

A sample lab experiment that provides learning experiences for each learning style is given in Appendix G. This sample lab answers the key questions Montgomery and Groat (1998) identify which are "Why are we learning this?" for Divergers, "What are the scientific theories?" for Assimilators, "How can I use this knowledge?" for Convergers, and "How can I apply this knowledge in other contexts?" for Accommodators.

## CAEQ Attitude Data

Research by Yucel (2007) showed that those with more positive attitudes about Chemistry were more successful in their Chemistry courses than those with less positive attitudes. However, in this research, this was not found. While each course reported positive scores for both overall CAEQ attitude, as well as each of the four subscales, no correlations of class data to final course grade were found for CHEM 1P00, CHEM 1F92, CHEM 2P20, nor CHEM 2P42. The only correlations were for males in CHEM 2P20: overall CAEQ attitude was positively correlated to course grade, and attitude towards leisure interest in science was positively correlated to course grade.

Previous research, such as that by Dalgety, Coll, and Jones (2003), has shown that a positive attitude about Chemistry is likely to influence students' decisions to continue in Chemistry, regardless of their academic achievement. To improve students' attitudes, in an effort to have them continue in Chemistry, a mentorship program between first year students and upper year students could be established. This would be extremely beneficial for all first year students, but especially FFS, who need to quickly understand and adapt to the academic culture of university, but are often intimidated by their instructors. Successful mentorship programs such as the Chemistry Merit program have been demonstrated by Adams and Lisy (2007) which showed particularly high rates of success for students from underrepresented groups such as African American and Latino populations. Similarly, Parkinson (2009) found that students who were involved in peer assisted learning support (PALS) showed substantial improvement in both their Chemistry and Calculus grades. Lockie and Van Lanen (2008) also found that supplemental instruction leaders also enjoyed positive benefits such as increased understanding of the material, greater self-confidence as a learner, and realization of the importance of the value of collaborative learning. Thus peer led learning had positive effects both for the peer leaders as well as the students. In addition, the formation of a Chemistry club could increase the sense of community for both sexes, and provide role models for both males and females in Chemistry.

## CAEQ Confidence Data

Dalgety and Coll (2006b) report that confidence is thought to be a better indicator of likelihood of continuing in Chemistry than actual achievement since achievement is subjective, and students will measure academic success in their courses differently. In this research, positive correlations were found in CHEM 1P00 between final course grade and: overall confidence, confidence discussing Chemistry, and the confidence in use of formulas. In CHEM 1F92, positive correlations were found between final course grade and: overall confidence, confidence discussing Chemistry, confidence in using formulas, and confidence in critical thinking in Chemistry. In CHEM 2P20, a positive correlation was found between final course grade and confidence discussing Chemistry. In CHEM 2P42, positive correlations were found between final course grade and: overall confidence, confidence discussing Chemistry, confidence in lab work, confidence using formulas, and confidence in critical thinking in Chemistry.

In each of the four courses studied, confidence discussing Chemistry was found to be correlated with final course grade. It is recommended that the Department of Chemistry continue to work closely with the Student Development Centre's Drop-in Science Help Centre as over 90% of help sought was for Chemistry 1F92. The primary purpose of the Drop-in Science Help Centre is to offer a relaxed and inviting source of science help for labs and assignments, and to provide assistance in understanding difficult lecture topics.

Tai and Sadler's (2007) study showed that two of the most effective teaching strategies are that of peer-led leading and the use of everyday examples to make abstract ideas more concrete, both of which occur in the Drop-in Science Help Centre. As well, since most students come regularly at the same time each week for lab and assignment help, study groups naturally form and provide a networking opportunity for students to get to know their classmates and discuss Chemistry. The Drop-in Science Help Centre is especially important for those students who might initially be too intimidated to speak with their Professors or lab demonstrators. The Drop-in peer staff encourages students to speak with their instructors, to slowly make students more self-confident in their ability to seek help directly from their instructors, to become more confident and to become less reliant on the Drop-in Help Centre services.

## Confidence of Males versus Females

Work by Andre et al. (1999) showed that males report higher self-efficacy than females in the physical sciences. Specifically, their work showed that males reported higher self-efficacy in skills such as explaining concepts to other students, proposing research questions that can be answered experimentally and applying theories and choosing the correct formula to solve a problem. In this work, there was no difference in scores between males and females in CHEM 1P00. In CHEM 1F92, males were significantly more confident overall, as well as in discussing Chemistry, in lab work, using formulas, and in their critical thinking. In CHEM 2P20, males' scores were higher in confidence overall, in discussing Chemistry, in lab work, and in their confidence with critical thinking. In CHEM 2P42, no differences were noted between males and females with respect to confidence.

Females are generally less confident in Chemistry than males and this lack of confidence could be a factor in limiting their pursuit of graduate studies. Females in first year report less confidence in their own abilities and are less likely to believe that their instructors and lab demonstrators believe they have the ability to go on in Chemistry. It is recommended that instructors and demonstrators encourage all students to continue in Chemistry courses and inform them about summer research positions within the department.

Although females were generally less confident than males concerning their abilities in Chemistry, one area in which females rated themselves high in confidence was in their ability to write about Chemistry. It is recommended that formal labs are introduced into first year Chemistry, for at least some of the laboratory experiments so that females will be able to demonstrate skill in scientific writing, an area in which they are generally quite confident.

## Self-Reported Family Pressure to Succeed

Self-reported family pressure to succeed data was reported by students on a Likert scale from 1-5 where 1 was no pressure and 5 was a great deal of pressure. While values were quite high, 3.60 with a standard deviation of 1.08 in CHEM 1F92, 3.37 with a standard deviation of 1.70 in CHEM 2P20, and 3.58 with a standard deviation of 1.35 in CHEM-2P42, the values were not found to be correlated with academic success in any of these courses. There was no difference in self-reported family pressure to succeed between males and females in any course, and also no difference in self-reported family pressure between FFS and NFFS in any of these three courses.

## Living Arrangements

In both CHEM 1F92 and CHEM 2P20, it was found that students who lived at home with their families achieved statistically higher final course grades than students who lived off-campus. Students who lived with their families achieved statistically higher final course grades than those who lived in residence in CHEM 1F92, while in CHEM 2P20, there was not a statistically significant difference between those who lived with their families and those who lived in residence. While it is a reality that many students must live either in residence or off-campus, it is recommended that departments work closely with Residence Life Coordinators and off-campus groups to provide workshops or help sessions on study skills and time management to handle the new freedoms and responsibilities that come with being in university, especially for those living either in residence or off-campus away from family.

## First in the Family Students

While previous research (U.S. Department of Education, 1998) showed that FGS are more likely to live with family than in residence or off-campus, this research did not show a similar relationship for FFS and NFFS. Since FGS are not as knowledgeable about expectations in university (Collier & Morgan, 2008), it is extremely helpful for instructors of first year courses to provide very clear guidelines of expectations and rubrics for each assignment. Students must know not only when the Professor's office hours are, but what the term "office hours" means. As well, university departments must work together to help all students, especially those in first year, know all the resources available to them, including math help centres, writing centres, academic skills workshops, learning skills services, and personal counseling.

While many students are successful with traditional teaching methods, it seems evident that varied instruction and additional resources to assist students in adapting to the academic culture of university would enhance the learning experience for all: students, lab demonstrators, and instructors.

## Limitations of this Work

There are several limitations of this work which must be considered. The CHEM 1P00 data is a small sample size as less than one-third of the class was present on the last day of class to complete the questionnaires. Those students who attended the final class are likely more motivated students, and therefore the sample is likely not representative of the class as a whole. In the CHEM 1F92 class, the data set was much larger, but again, since participation was voluntary, it is possible that the students who chose to participate in the research were not representative of the class as a whole. It is possible that students who were less confident in their ability in Chemistry would be less likely to participate as the consent forms outlined that agreeing to participate meant that the researchers would be able to access their final course grades.

As well, since the questionnaires in CHEM 1F92 were completed over a two week time span in individual lab sections, the students who completed the questionnaires earlier in the time span would have had fewer lectures than those who completed the questionnaires later in that two week time block. For example, if a difficult concept was introduced during that time period, those who completed the questionnaires after the difficult concept was taught might report less confidence than those who completed the questionnaires before the difficult concept was introduced.

In CHEM 2P42, there was a small sample size and 15 of the 39 students who participated in the research did not complete the course to obtain a final grade. In CHEM 2P20, three different groups of CHEM 2P20 students comprised the total data set (two Spring sessions, and one Fall session) and questionnaires were completed at the beginning of the Fall session, but at the final lecture or tutorial of the Spring sessions. Therefore, students would have had differing amounts of experience with Organic Chemistry depending on when in the term the questionnaires were administered.

Finally, learning styles are not fixed characteristics but rather are preferences that depend strongly on the situation. Therefore, test-retest reliability is often not high. Although the Kolb LSI was modified to specify learning in Chemistry, a student could interpret this to mean learning in the lecture, laboratory, or tutorial setting, depending perhaps on where the questionnaire was completed. To increase test-retest reliability and to ensure that each student is thinking of the same learning environment, the modified introductory statements could be made more specific. For example, "I learn Chemistry best when" could be made more specific by modifying it further to "I learn Chemistry concepts in lecture best when" or "I learn Chemistry lab skills best when". Further research with testing occurring in the same situation of lecture, lab, or tutorial, would make data collection more consistent and increase the likelihood that each student is thinking of the same learning situation in each administration of the questionnaire package.

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# APPENDICES

Appendix A: Script to Address Students

**Verbal Script**

Hello, my name is Elizabeth Ilnicki-Stone and as part of my Graduate Studies in Chemistry here at Brock, I am conducting a research study entitled "How Learning Styles, Chemistry Attitudes and Experiences, and Other Factors Affect Academic Success in First and Second Year Chemistry." Today, your instructor Dr.{insert name}has kindly allowed me to address you in order to invite you to participate in this research study. This study has received ethics clearance through Brock University's Research Ethics Board and the file number is {insert number here}.

The purpose of my research project is to determine what correlations exist, if any, between the learning styles of students, their chemistry attitudes and experiences, factors such as age and education background, and their level of academic success achieved in first and second year chemistry courses.

Your participation in this study is completely voluntary. If you do not wish to participate, there is no penalty. Also, if you initially agree to participate, but during the course of the study decide to withdraw, this is your right, and there is absolutely no penalty for doing so. Further, if after completing the study you do not wish to have your results included, you can indicate so, and any information you have provided and any consent forms that you would have signed will be destroyed through confidential shredding. Your participation in this study will have no effect on this, or any other chemistry courses you are taking or will take.

If you choose to participate, you will be asked to complete three questionnaires; a Modified Kolb Learning Skills Inventory for Chemistry Students, the Chemistry Attitudes and Experiences Questionnaire, and a questionnaire regarding information about yourself such as your major, age range, and whether or not you are employed during the academic year. However, the three questionnaires might not necessarily be given in that exact order. Participation will take approximately 30 minutes of your time.

In order to correlate your responses to these questionnaires with academic success, we also ask permission to access your academic records to obtain your grades in this course, and to obtain information such as the number of credits you have completed, and your grades in high school courses. We also ask your permission to access your academic records in subsequent years, to a maximum of two years, in order to determine what chemistry courses you chose to take, and your academic success in those courses.

Any data that you provide, including personal identifiers such as your name and student number, your responses to the questionnaires, and your academic records are kept confidential. This data will only be available to myself and the other two Principal Investigators, Ian Brindle, who is my project supervisor and a Professor in Chemistry, and David DiBattista, a Professor in Psychology. Since our interest is in the average responses of the group of participants, you will not be identified individually in any way in written reports of this research or presentations. Data collected during this study will be stored in a locked cabinet in my lab area, and electronic data will only by accessible to the Principal Investigators and myself. The raw data will be kept for 2 years after which time the questionnaires will be shredded, and any electronic data with personal identifiers will be deleted.

Although you will not get compensation for participation in this study, there will be a draw to win one of # (depends on the group size, approximately 1 in 50) gift certificates to the Pen Centre valued at $50. The odds of winning a gift certificate are approximately 1 in 50. This draw will occur immediately after all the completed and not completed surveys have been turned in. Each person who remains to either complete the survey or work on the sample test/exam questions will be able to participate in the draw. You will find your ticket in the envelope along with the surveys, as well as sample test and exam questions if you would prefer to remain to work on those instead of completing the surveys.

As a graduate student, I am also a lab demonstrator in the first year Chemistry 1P00 course. For those students that have me as their lab demonstrator, I would just like to stress that whether you choose to participate or not will not be known to me until after the completion of the course and after all the final grades have been submitted. Until that time, all data will remain in the sealed envelopes so I will not know the identity of the participants.

I am now handing out the envelopes which contain the Invitation Letter and Informed Consent Forms which I would ask you to read carefully. If you have any questions please feel free to ask. Again, participation is strictly voluntary and you can choose not to participate without any penalty.

(Allow time for students to read the forms)
(Ask for questions and respond to any questions or concerns)

If you would like to participate, please write your name and date on the Informed Consent Form, and sign the bottom of the form.

As mentioned, you will be asked to complete three questionnaires. The questionnaires are in envelopes which are being passed out. If you would rather not complete the questionnaires, there are also sample test/exam questions in the envelope which you can work on. If you choose to complete the questionnaires, please complete them in the order that you find them in your envelope. Please read over the directions carefully as each page requests that you choose your response in a different manner.

Please note that for the Modified Kolb Learning Styles Inventory for Chemistry Students, you are asked to rank 4 statements by assigning numbers between 1 and 4, using each number once. In this case, you assign the highest number of points to the statement that best describes you.

(Show the example from the questionnaire on the overhead and stress that the statement which is most like them gets the highest point value, and decreasing values for those statements which describe them to a lesser degree.)

If you have any questions while completing the questionnaires, please do not hesitate to ask. You can work in pen or pencil for these questionnaires.

Once you have completed all the questionnaires, please ensure that you have put your name or name and student number on each. Next, put them back into the envelope in the order that they originally were, and seal the envelope signing your name across the seal at the back.

(Show them an example of signing across the seal)

Once they are in their sealed envelopes, please put them into the boxes located at the front of the room and pick up an extra copy of the informed consent form. This form will give you information about the study as well as contact information for me if you have any questions about the research study. As well, it includes the contact information for the Research Ethics Officer if you have any questions or concerns regarding your rights as a research participant. Also, please drop off your half of the ticket which is in your envelope into the ballot box with your completed or not completed surveys. The draw will occur once all surveys, complete and incomplete, have been returned.

Are there any questions at this time?

Thank you very much for taking the time to participate.

(Begin putting boxes for completed questionnaires and the ballots at the front of the room as well as extra copies of the Informed Consent Form)

(Be available for questions until all students have completed the questionnaires and have left the room)

Appendix B: Sample Letter of Invitation

September, 2009

**Title of Study:** How Learning Styles, Chemistry Attitudes and Experiences, and Other Factors Affect Academic Success in First and Second Year Chemistry

**Principal Investigators:** Ian D. Brindle, Professor of Chemistry, Dean of Math and Science, Brock University
David DiBattista, Professor of Psychology, Brock University

**Principal Student Investigator:** Elizabeth Ilnicki-Stone, MSc Graduate Student, Department of Chemistry, Brock University

**Faculty Supervisor:** Ian D. Brindle, Professor of Chemistry and Dean of Math and Science, Brock University

We, Ian Brindle, David DiBattista, and Elizabeth Ilnicki-Stone, from the Departments of Chemistry and Psychology, Brock University, invite you to participate in a research project entitled "How Learning Styles, Chemistry Attitudes and Experiences, and Other Factors Affect Academic Success in First and Second Year Chemistry."

The purpose of this research project is to determine how a student's learning style, chemistry attitudes and experiences, and other factors such as educational background affect academic success in first and second year chemistry courses. The expected duration of your participation is approximately 30 minutes. This research will benefit educators at the university level by providing a better understanding of the correlation between learning styles, attitudes about chemistry, demographic factors, and the academic success of students taking first and second year chemistry courses. This increased understanding could result in modification of teaching methods to address learning styles and improve student academic success. Also, students will have the opportunity to learn more about their individual learning style, which can improve their knowledge of how they learn, allowing them to build on their strengths.

This research is occurring only at Brock University, and data will not be shared with any other organization. Your participation in this project is strictly voluntary, and you may withdraw at any time. Your choice to participate or not to participate will have no effect on your grade in this or any other chemistry course you take. All information provided will be kept confidential and you will not be identified individually in any way in written reports or presentations of this research.

If you have any pertinent questions about your rights as a research participant, please contact the Brock University Research Ethics Officer at (905) 688-5550 ext. 3035or reb@brocku.ca.

If you have any questions, please feel free to contact any of us.

Thank you,


Ian D. Brindle
Professor of Chemistry and
Dean of Math and Science
Brock University
905-688-5550 ext. 3421
ibrindle@brocku.ca

David DiBattista
Professor of Psychology,
Faculty of Social Sciences
Brock University
905-688-5550 ext. 3467
David.DiBattista@brocku.ca

Elizabeth Ilnicki-Stone
MSc Graduate Student
Department of Chemistry
Brock University
905-688-5550 ext. 5520
eilnickistone@brocku.ca

Faculty Supervisor: Ian D. Brindle, Professor of Chemistry and Dean of Math and Science, Brock University
905-688-5550 ext. 3421, ibrindle@brocku.ca


**This study has been reviewed and received ethics clearance through Brock University's Research Ethics Board (File #07-264).**

Appendix C: Sample Informed Consent Form

# Informed Consent Form

**Date:** September, 2009.
**Project Title:** How Learning Styles, Chemistry Attitudes and Experiences, and Other Factors Affect Academic Success in First and Second Year Chemistry

**Principal Investigators:**
Ian D. Brindle, Professor of Chemistry and Dean of Math and Science, Brock University
(905) 688-5550 ext. 3421, ibrindle@brocku.ca
David DiBattista, Professor of Psychology, Brock University
(905) 688-5550 ext. 3467, David.DiBattista@brocku.ca
**Principal Student Investigator:** Elizabeth Ilnicki-Stone
MSc graduate student, Department of Chemistry, Brock University
(905) 688-5550 ext. 5520, eilnickistone@brocku.ca

**Faculty Supervisor:**
Ian D. Brindle, Professor of Chemistry
Department of Chemistry
Brock University
(905) 688-5550 ext. 3421, ibrindle@brocku.ca

**INVITATION**
You are invited to participate in a study that involves research. The purpose of this study is to determine how learning style, attitudes regarding chemistry, and other factors such as age and educational background affect academic success in first and second year chemistry courses.

**WHAT'S INVOLVED**
As a participant, you will be asked to complete the a modified Kolb Learning Skills Inventory for Chemistry students, the Chemistry Attitudes and Experiences Questionnaire, and a questionnaire regarding information about yourself such as your major, age range, and whether or not you are employed during the academic year. Participation will take approximately 30-45 minutes of your time. We also ask permission to access your Brock University academic records to obtain your grades in this course, and to obtain information such as the number of credits you have completed, and your grades in relevant high school courses. This is to determine what, if any, correlations exist between your responses to the questionnaires, and your performance in chemistry courses. Also, student academic records of chemistry courses will be tracked for a maximum of two more years to determine your choice of subsequent chemistry courses and your success in those chemistry courses.

**POTENTIAL BENEFITS AND RISKS**
A possible benefit of participation includes a better understanding of your individual learning style. This information will be offered to participants in the form of a feedback letter. Also, this study will help educators have a better understanding of what teaching methods would work best for students taking first and second year chemistry courses. There are no known or anticipated risks associated with participation in this study. Although you will not get compensation for participation, a random draw for $50 gift certificates to the Pen Centre will occur after the surveys (completed or not completed) have been returned. The odds of winning are about 1 in 50 depending on the class size. If you choose not to participate in the study, you will still be included in the draw.

**CONFIDENTIALITY**

All information that you provide is considered confidential; your name will not be included or in any other way associated with the data collected in the study. Furthermore, because our interest is in the average responses of the entire group of participants, you will not be identified individually in any way in written reports of this research. Data collected during this study will be stored in a locked cabinet in the Principal Student Investigator's lab area, and electronic data will only by accessible to the Principal Investigators and Principal Student Investigator. The raw data will be kept for 2 years after which time the questionnaires will be shredded, and any electronic data with personal identifiers will be deleted. Only if the Principal Student Investigator is not a Lab Demonstrator, Teaching Assistant, or otherwise affiliated with any chemistry course during an academic year, can data analysis begin before final grades are submitted. Otherwise, all data will remain in the sealed envelopes until all final grades have been submitted.

**VOLUNTARY PARTICIPATION**
Participation in this study is voluntary. If you wish, you may decline to answer any questions or participate in any component of the study. Further, you may decide to withdraw from this study at any time and may do so without any penalty or loss of benefits to which you are entitled. Your decision to participate, or not to participate, will have no effect on your course grades in either this course or any other subsequent chemistry courses.

**PUBLICATION OF RESULTS**
Results of this study may be published in professional journals and presented at conferences. Feedback about this study will be available by contacting Elizabeth Ilnicki-Stone by e-mail at eilnicki@brocku.ca after May of 2010.

**CONTACT INFORMATION AND ETHICS CLEARANCE**
If you have any questions about this study or require further information, please contact the Principal Student Investigator, Elizabeth Ilnicki-Stone, or the Faculty Supervisor, Ian D. Brindle, using the contact information provided above. This study has been reviewed and received ethics clearance through the Research Ethics Board at Brock University (File #07-264). If you have any comments or concerns about your rights as a research participant, please contact the Research Ethics Office at (905) 688-5550 ext. 3035, reb@brocku.ca.

Thank you for your assistance in this project. Please keep a copy of this form for your records.

**CONSENT FORM**
I agree to participate in this study described above. I have made this decision based on the information I have read in the Information-Consent Letter. I have had the opportunity to receive any additional details I wanted about the study and understand that I may ask questions in the future. I understand that I may withdraw this consent at any time.

Name: ______________________________ Student Number: ________________

Signature: ____________________________ Date: ________________________

## Appendix D: Modified Kolb Learning Styles Inventory

**Modified Kolb Learning Style Inventory for Chemistry 1F92 Students**

**Name:** ______________________ **Student Number:** ______________

Please complete the following questions.

Example: If you love chocolate, really like potato chips, somewhat like donuts, but hate broccoli, you would rate the items as follows:

**As a snack, I prefer:**

_3_ potato chips _4_ chocolate _1_ broccoli _2_ donuts

**Remember, assign the highest values to those that are most like you.**

4=MOST LIKE YOU 3=SECOND MOST LIKE YOU 2=THIRD MOST LIKE YOU 1=LEAST LIKE YOU

| | | | |
|---|---|---|---|
| **1. When I learn Chemistry:** | | | |
| ___ I like to deal with my feelings. | ___ I like to think about ideas. | ___ I like to be doing things. | ___ I like to watch and listen. |
| **2. I learn Chemistry best when:** | | | |
| ___ I listen and watch carefully. | ___ I rely on logical thinking. | ___ I trust my hunches and feelings. | ___ I work hard to get things done. |
| **3. When I am learning Chemistry:** | | | |
| ___ I tend to reason things out. | ___ I am responsible about things. | ___ I am quiet and reserved. | ___ I have strong feelings and reactions. |
| **4. I learn Chemistry by:** | | | |
| ___ feeling. | ___ doing. | ___ watching. | ___ thinking. |
| **5. When I learn Chemistry:** | | | |
| ___ I am open to new experiences. | ___ I look at all sides of issues. | ___ I like to analyze things, break them down into their parts. | ___ I like to try things out. |
| **6. When I am learning Chemistry:** | | | |
| ___ I am an observing person.. | ___ I am an active person. | ___ I am an intuitive person. | ___ I am a logical person. |
| **7. I learn Chemistry best from:** | | | |
| ___ observation. | ___ personal relationships. | ___ rational theories. | ___ a chance to try out and practice. |
| **8. When I learn Chemistry:** | | | |
| ___ I like to see results from my work. | ___ I like ideas and theories. | ___ I take my time before acting. | ___ I feel personally involved in things. |
| **9. I learn Chemistry best when:** | | | |
| ___ I rely on my observations. | ___ I rely on my feelings. | ___ I can try things out for myself. | ___ I rely on my ideas. |
| **10. When I am learning Chemistry:** | | | |
| ___ I am a reserved person. | ___ I am an accepting person. | ___ I am a responsible person. | ___ I am a rational person. |
| **11. When I learn Chemistry:** | | | |
| ___ I get involved. | ___ I like to observe. | ___ I evaluate things. | ___ I like to be active. |
| **12. I learn Chemistry best when:** | | | |
| ___ I analyze ideas. | ___ I am receptive and open-minded. | ___ I am careful. | ___ I am practical. |

Appendix E: Sample Modified Chemistry Attitudes and Experiences Questionnaire

## CHEMISTRY ATTITUDES AND EXPERIENCES QUESTIONNAIRE (CAEQ)

Student Number

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |

**The information you submit in this survey will NOT be reported on an individual basis. It will be reported on an aggregate level.**

### PERCEPTIONS

1) Please rate the perceptions you have about chemistry and related topics. For example, if you feel chemistry is mostly about the study of natural substances, and only a little about the study of synthetic material then mark your answer like this:

**Chemistry:** Natural Substances O ● O O O O O Synthetic Material

***Chemists***

| | | |
|---|---|---|
| athletic | O O O O O O O | unfit |
| socially aware | O O O O O O O | socially unaware |
| environmentally aware | O O O O O O O | environmentally unaware |
| flexible in their ideas | O O O O O O O | fixed in their ideas |
| care about the effects of their results | O O O O O O O | only care about their results |
| imaginative | O O O O O O O | unimaginative |
| friendly | O O O O O O O | unfriendly |
| inquisitive | O O O O O O O | indifferent |
| patience | O O O O O O O | impatient |

***Chemistry Research***

| | | |
|---|---|---|
| helps people | O O O O O O O | harms people |
| improves quality of life | O O O O O O O | decreases quality of life |
| solves problems | O O O O O O O | creates problems |
| advances society | O O O O O O O | causes society to decline |

***Science Documentaries***

| | | |
|---|---|---|
| enjoyable | O O O O O O O | boring |

***ChemistryWeb Sites***

| | | |
|---|---|---|
| interesting | O O O O O O O | boring |

***Chemistry Jobs***

| | | |
|---|---|---|
| challenging | O O O O O O O | easy |
| varied | O O O O O O O | repetitive |
| interesting | O O O O O O O | boring |
| satisfying | O O O O O O O | unsatisfying |
| exciting | O O O O O O O | tedious |

***Talking to my friends about Chemistry***

| | | |
|---|---|---|
| interesting | O O O O O O O | boring |

***Science fiction movies***

| | | |
|---|---|---|
| interesting | O O O O O O O | boring |

## CHEMISTRY ATTITUDES AND EXPERIENCES QUESTIONNAIRE (CAEQ)

This part of the questionnaire investigates the confidence ***YOU HAVE IN UNDERTAKING DIFFERENT TASKS***.
For example: If you feel very confident about talking to a scientist about chemistry:

Please indicate how *CONFIDENT YOU* feel about talking to a scientist about chemistry
Totally confident __ √ __ __ __ Not confident

*Please indicate how **CONFIDENT YOU** feel about*

| | | |
|---|---|---|
| 1 | Talking to a scientist about chemistry | Totally confident __ __ __ __ __ Not confident |
| 2 | Achieving a passing grade in a chemical safety quiz | Totally confident __ __ __ __ __ Not confident |
| 3 | Reading the procedures for an experiment and conducting the experiment without supervision | Totally confident __ __ __ __ __ Not confident |
| 4 | Designing and conducting a chemistry experiment | Totally confident __ __ __ __ __ Not confident |
| 5 | Tutoring another student in a first year chemistry course | Totally confident __ __ __ __ __ Not confident |
| 6 | Determining what answer is required from a written description of a chemistry problem | Totally confident __ __ __ __ __ Not confident |
| 7 | Ensuring that data obtained from an experiment is accurate | Totally confident __ __ __ __ __ Not confident |
| 8 | Proposing a meaningful question that could be answered experimentally | Totally confident __ __ __ __ __ Not confident |
| 9 | Explaining something that you learnt in this chemistry course to another person | Totally confident __ __ __ __ __ Not confident |
| 10 | Choosing an appropriate formula to solve a chemistry problem | Totally confident __ __ __ __ __ Not confident |
| 11 | Knowing how to convert the data obtained in a chemistry experiment into a result | Totally confident __ __ __ __ __ Not confident |
| 12 | After reading an article about a chemistry experiment, writing a summary of the main points | Totally confident __ __ __ __ __ Not confident |
| 13 | Learning chemistry theory | Totally confident __ __ __ __ __ Not confident |
| 14 | Determining the appropriate units for a result determined using a formula | Totally confident __ __ __ __ __ Not confident |
| 15 | Writing up the experimental procedures in a laboratory report | Totally confident __ __ __ __ __ Not confident |
| 16 | After watching a television documentary dealing with some aspect of chemistry, writing a summary of its main points | Totally confident __ __ __ __ __ Not confident |
| 17 | Achieving a passing grade in a subsequent chemistry course, such as CHEM 1F92 | Totally confident __ __ __ __ __ Not confident |
| 18 | Applying theory learnt in a lecture for a laboratory experiment | Totally confident __ __ __ __ __ Not confident |
| 19 | Writing up the results section in a laboratory report | Totally confident __ __ __ __ __ Not confident |
| 20 | After listening to a public lecture regarding some chemistry topic, explaining its main ideas to another person | Totally confident __ __ __ __ __ Not confident |

## CHEMISTRY ATTITUDES AND EXPERIENCES QUESTIONNAIRE (CAEQ)

This part of the questionnaire ***LOOKS AT YOUR EXPERIENCES DURING YOUR FIRST YEAR CHEMISTRY CLASSES.***

Please answer these questions considering ALL your experiences during your first-year chemistry classes. For example if you thought that THREE out of FOUR of your lecturers encouraged you to enroll in the chemical hazards course, you would answer the following question:

| | Strongly Agree | Agree | Neither | Disagree | Strongly Disagree |
|---|---|---|---|---|---|
| a. My lecturers encouraged me to enroll in chemical hazards | SA | (A) | N | D | SD |

| ***Please answer these questions about your LECTURE classes*** | | | | | |
|---|---|---|---|---|---|
| 1 The lecture material was relevant to the objectives of the course | SA | A | N | D | SD |
| 2 My lecturers were interested in my progress in chemistry | SA | A | N | D | SD |
| 3 The concepts introduced in the lecture materiel were explained clearly | SA | A | N | D | SD |
| 4 My lecturer encouraged me to take further chemistry courses | SA | A | N | D | SD |
| 5 The lecture notes were interesting | SA | A | N | D | SD |
| 6 The chemistry lecturers have made me feel that I have the ability to continue in science | SA | A | N | D | SD |
| 7 The lecture notes were clearly presented | SA | A | N | D | SD |
| 8 It was easy to find a lecturer to discuss e problem with | SA | A | N | D | SD |
| 9 The lectures were presented in en interesting menner | SA | A | N | D | SD |
| 10 The lecturers explained problems clearly to me | SA | A | N | D | SD |

| ***Please answer these questions about your TUTORIAL classes*** | | | | | |
|---|---|---|---|---|---|
| 11 The tutorial problems covered all parts of the course | SA | A | N | D | SD |
| 12 My tutors were interested in my progress in chemistry | SA | A | N | D | SD |
| 13 The problems worked on in tutorial were relevant to the course | SA | A | N | D | SD |
| 14 My tutors encouraged me to take further chemistry courses | SA | A | N | D | SD |
| 15 The tutorial questions helped me understand the lecture course | SA | A | N | D | SD |
| 16 The chemistry tutors have made me feel I have the ability to continue in science | SA | A | N | D | SD |
| 17 The material presented in tutorials was useful | SA | A | N | D | SD |
| 18 The material covered in tutorials was presented in an interesting manner | SA | A | N | D | SD |
| 19 It was easy to find a tutor to discuss a problem with | SA | A | N | D | SD |
| 20 The tutors explained problems clearly to me | SA | A | N | D | SD |

| ***Please answer these questions about your LABORATORY classes*** | | | | | |
|---|---|---|---|---|---|
| 21 The laboratory manual contained instructions that were easy to follow | SA | A | N | D | SD |
| 22 When writing-up experiments in my laboratory book, the relationship between the data and the results was clear | SA | A | N | D | SD |
| 23 My demonstrators were interested in my progress in chemistry | SA | A | N | D | SD |
| 24 The practical experiments were related to lectures | SA | A | N | D | SD |
| 25 What is required in the write-up of an experiment is clear | SA | A | N | D | SD |
| 26 My demonstrators encouraged me to take further chemistry courses | SA | A | N | D | SD |
| 27 The theory behind the experiments was clearly presented | SA | A | N | D | SD |
| 28 The purpose of the calculations required for laboratory books write-up was clear | SA | A | N | D | SD |
| 29 The chemistry demonstrators have made me feel I have the ability to continue in science | SA | A | N | D | SD |
| 30 The laboratory manual, experimental techniques and write-up were all interlinked | SA | A | N | D | SD |
| 31 What was required in the questions when writing up the laboratory book was clear | SA | A | N | D | SD |
| 32 It was easy to find a demonstrator to discuss a problem with | SA | A | N | D | SD |
| 33 The experiments were interesting | SA | A | N | D | SD |
| 34 The amount of work required when writing up the laboratory book was appropriate for the amount of the assessment | SA | A | N | D | SD |
| 35 The demonstrators explained problems clearly to me | SA | A | N | D | SD |

Appendix F: Sample Demographics Survey

How Learning Styles, Chemistry Attitudes and Experiences, and Other Factors Affect Academic Success in First and Second Year Chemistry Student Survey
Chemistry 1F92, September, 2009

Name: ______________________________

Student Number: ________________________

**Unless otherwise stated, please circle one response.**

1. How many courses are you currently enrolled in? 1 2 3 4 5 6

2. Were you previously enrolled in this course? Yes No

3. What is your major? If undeclared, write undeclared. ______________________

4. In your Chemistry 1F92 lectures, where do you generally sit?

   Near the front of the class In the middle of the class Towards the back of the class

5. Did you attend high school in Ontario? Yes No

   If yes, which of the following courses did you take? Please check **all** those that apply.

   Gr. 11 Chemistry _____
   Gr. 12 Chemistry _____
   Gr. 12 Calculus _____
   Gr. 12 Algebra and Geometry _____
   Gr. 12 Finite/Statistics _____

6. What is the highest level of education that you plan to complete?

   Pass degree Honours Masters PhD MD Teacher's College

7. What grade do you reasonably expect to achieve in Chemistry 1F92? Please check 1 range.
   90-100% _____
   80-89% _____
   70-79% _____
   60-69% _____
   50-59% _____
   < 49% _____

8. How much pressure is there from your immediate family to succeed academically in this university course? Please check the response that corresponds to your current situation. (1 = no pressure, 5 = a great deal of pressure)

| ___ | ___ | ___ | ___ | ___ |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

9. If you had a question about a concept in chemistry that you didn't understand, what would you do? Please order the following statements from 1-5 describing what you would do. Please assign each number from 1-5 only once.

1 = Most likely to do
2 = Second most likely to do
3 = Third most likely to do
4 = Fourth most likely to do
5 = Least likely to do

___ I would seek help from someone affiliated with the course (ex. instructor, lab demonstrator)

___ I would seek help from a classmate and/or friend in the course

___ I would seek help from a friend or family member who is not currently taking this course

___ I would seek help from a tutor or the Student Development Centre's Drop-In program

___ I would not seek help from others. I would try to figure it out myself by reading the textbook and other course materials, or by searching on-line.

10. Are you employed and/or do volunteer work during the academic year? Yes No
If yes, approximately how many hours per week are you employed and/or volunteer? _____ hours

11. Are you involved in varsity sports this term? Yes No
If yes, approximately how many hours per week does this take of your time? _____ hours

12. Please circle your response.
I am male I am female I prefer not to answer

13. Are you the first in your immediate family to attend university? Yes No
If no, please circle **all** those who attended university before you.

Mother Father Siblings

14. During the academic year, what description best describes your living arrangement?
I live with my family.
I live off-campus, but not with my family.
I live in residence.

15. Are you currently raising children under the age of 18? Yes No
If yes, please indicate how many. ______

16. Please indicate your age range by checking the appropriate box.
a. 18 or younger _____
b. 19-24 _____
c. 25 and older _____

17. Is English your primary language? Yes No
If no, please indicate your primary language. __________________________

Thank you very much for taking the time to complete this survey!

## Appendix G: Determination of the Value of a Copper Coating on a Post-1982 American Cent: Laboratory Incorporating All Four of Kolb's Learning Styles

**Background:** The practice of coating less expensive metals with a thin layer of a more expensive metal has quite a history. Archimedes of Syracuse was a Greek mathematician, physicist, engineer, and astronomer who was asked to determine if a King's crown was pure gold or if the King had been cheated with a crown of gold plated silver. However, Archimedes was not allowed to destroy the crown. While Archimedes was taking a bath, he realized that the volume of water displaced by his body in the bathtub was equal to the volume which was submerged. Archimedes could obtain the volume of the crown, and combined with the mass, he could obtain the density. He could then compare the density of the crown to gold and silver to determine the crown's composition.

American cents were made almost completely of copper until pure copper became too expensive to use. It was decided to mint American cents from zinc coated with copper. If an American cent has a date before 1982, it is made of 95% copper. If the date is 1983 or later, it is made of 97.5% zinc and plated with a thin copper coating. Some cents produced in the transition year of 1982 were made of pure copper while others are the copper coated zinc.

**Single displacement reactions** involve the reaction of an element with a compound to produce a different element and a different compound:

$$A + BC \rightarrow AC + B$$

However, single replacement reactions do not always occur. In a metal displacement reaction, the metal to be displaced must be less reactive than the metal that is doing the displacing. These same rules apply for non-metal displacement.

An activity series can predict whether or not a single displacement reaction will occur. The activity series of metals is a list typically arranged in terms of decreasing relative reactivity. Metals with greater reactivity are arranged higher than metals with lower reactivity. If the metal that is doing the displacing is located higher on the activity series than the metal that is being displaced, then the reaction will occur. If not, then no reaction will occur. In this experiment, the reaction of hydrochloric acid with the zinc core of the cent will result in a hollow cent being produced. The single displacement reaction is as follows:

$$Zn(s) + 2\ HCl\ (aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

The relative reactivities of zinc and copper can be determined by comparing how they behave in hydrochloric acid. Since the reaction occurs with the zinc core, but not with the copper coating, zinc is a more reactive metal than copper. Therefore, zinc would be arranged higher on an activity series than copper.

In this lab, you will identify ways to determine if a cent is pure copper or only copper-coated zinc based on the physical properties of the two metals, determine the percent copper of a copper-coated zinc cent using chemical properties of the two metals, and calculate the value of the savings by switching from pure copper to copper coated zinc in cent production.

**Materials**

Pre-1982 American cent
Post-1982 American cent
6M Hydrochloric acid, HCl (aq)
250 mL beaker
Metal file
Tongs
Analytical balance

**Safety Precautions**

Hydrochloric acid is very corrosive. Wash skin thoroughly if it comes in contact with skin. Wear goggles at all times. If HCl does come in contact with eyes, rinse thoroughly for 15 minutes, and seek medical attention.

**Data Table**

| | |
|---|---|
| Mass of Pre-1982 Cent | |
| Initial Mass of Post-1982 Cent | |
| Final Mass of Post-1982 Cent | |
| Difference in Mass of the Post-1982 Cent (Mass of Zinc reacted) | |
| Cost of Zinc (per pound) | |
| Cost of Copper (per pound) | |

**Procedure:**

1. Take one pre-1982 cent and one post-1982 cent. Work in pairs to answer the question "Other than looking at the year, how could you tell which coin is pre-1982 and which coin is post-1982 using the physical properties of the coins?" Fill this in on your report sheets.

2. Obtain and record the mass of each cent on the analytical balance.

3. Using a metal file, etch the post-1982 cent along the edge until you see the silver coloured zinc.

4. Carefully pour about 25 mL of the 6M HCl into your beaker. Using the tongs, slowly drop the post-1982 cent into the beaker. Allow the reaction to occur. Record your observations.

5. When the reaction is complete (production of gas has stopped), remove the cent from the acid using the tongs. Rinse the cent with tap water, and allow it to dry on a paper towel before getting the mass. Record your observations both of the cent and of the HCl solution. When dry, obtain the mass of the cent and record.

6. Pour the HCl into the waste container in the fume hood and clean all glassware and equipment.

7. Record the costs of zinc and copper, given on the board, into your data table.

8. The post-1982 cents can either be kept, after being rinsed thoroughly, or put into the labeled box at the front. Please put the pre-1982 cents back into the labeled box at the front of the lab.

**Determination of the Value of a Copper Coating on a Post-1982 American Cent Laboratory Incorporating All Four of Kolb's Learning Styles Student Report Sheets**

1. Other than looking at the year, name two ways in which you could you tell which coin is pre-1982 and which coin is post-1982.

2. Write the reaction that occurs when the post-1982 cent is put into the HCl.

3. Assuming 100% copper in the pre-1982 cent, determine its cost.

4. Determine the cost of copper in the post-1982 cent.

5. Determine the cost of zinc in the post-1982 cent.

6. Determine the total cost of the post-1982 cent.

7. Calculate how much is saved per cent by coating zinc with copper.

8. If 1,000,000 cents are minted, determine the savings.

9. List two or three other examples of where coated metals could replace pure metals to save costs?

10. What % by mass of the post-1982 cent is copper? Zinc?

11. How many old (pre-1982) cents are there in a pound? Your answer should be approximately 146. Show your work. What is the face value in dollars of this many cents?

12. What are the sources of error in this experiment?

**Calculations with Moles**

Show all work and use units and the correct number of significant figures.

1. Calculate the moles of Cu in the post-1982 cent.

2. Calculate the moles of Zn reacted.

3. Calculate the atoms of Zn reacted.

4. Calculate the moles of $H_2$ given off based on the zinc reacted.

5. Calculate the volume of $H_2$ given off assuming STP conditions.

6. Calculate the molecules of $H_2$ given off.

7. How many moles of hydrochloric acid were actually needed?

8. How many moles of HCl did you start with?

9. How many post-1982 American cents would you need to react at STP with HCl to fill a room with Hydrogen gas if the room's dimensions are 12m long, 10 m wide, and 12.5 m high.

10. Why do newer cents weigh less even though they are the same size as the old ones?

Determination of the Value of a Copper Coating on a Post-1982 American Cent Laboratory Incorporating All Four of Kolb's Learning Styles Student Report Sheets With Answers

1. Other than looking at the year, name two ways in which you could you tell which coin is pre-1982 and which coin is post-1982.

Possible Answers:

Take the mass of each and compare to the density of each metal. Copper cents weigh approximately 3.1 grams, whereas the zinc cents weigh only approximately 2.5 grams. http://coins.about.com/od/uscoins/f/copper_to_zinc.htm.

Drop both coins onto a hard surface, and listen to the distinctive sound of each. Zinc cents have a flat sound, whereas copper cents have a higher-pitched, more melodious "ring" sound. http://coins.about.com/od/uscoins/f/copper_to_zinc.htm.

Use the large difference in the melting points of copper and zinc.
Melting Point of Copper = 1,083°Celsius (=1,981°Fahrenheit)
Melting Point of Zinc = 419.6°Celsius (=787°Fahrenheit)
(http://www.1728.com/projects.htm)
Zinc cents can be melted in a Bunsen burner while a copper cent cannot. The zinc cent will easily melt in the Bunsen burner flame. The copper cent will certainly get hot, it will even start to glow but it WON'T melt.

2. Write the reaction that occurs when the post-1982 cent is put into the HCl.

$$Zn(s) + 2\ HCl\ (aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

3. Assuming 100% copper in the pre-1982 cent, determine its cost.

$$\text{gram Cu} \times \frac{1\ \text{lb.}}{454\ \text{g Cu}} \times \frac{\text{cents}}{\text{lb}} = \text{cents}$$

4. Determine the cost of copper in the post-1982 cent.

$$\text{gram Cu} \times \frac{1\ \text{lb.}}{454\ \text{g Cu}} \times \frac{\text{cents}}{\text{lb}} = \text{cents}$$

5. Determine the cost of zinc in the post-1982 cent.

$$\text{gram Zn} \times \frac{1\ \text{lb.}}{454\ \text{g Zn}} \times \frac{\text{cents}}{\text{lb}} = \text{cents}$$

6. Determine the total cost of the new cent.

Cost of Copper (from 4) + Cost of Zinc (from 5)

7. Calculate how much is saved per cent by coating zinc with copper.

   Cost calculated in Question 3-Cost calculated in Question 6

8. If 1,000,000 cents are minted, determine the savings.

   Savings per cent calculated in Q7 multiplied by 1,000,000

9. List two or three other examples of where coated metals could replace pure metals to save costs?

   Jewelry, household appliances, faucets, etc.

10. What % by mass of the post-1982 cent is copper? Zinc?

$$\% \text{ Cu} = \frac{\text{Mass of cent after reaction}}{\text{Initial mass of unreacted cent}} \times 100\%$$

$$\% \text{ Zn} = \frac{\text{Mass lost in the reaction}}{\text{Initial mass of unreacted cent}} \times 100\%$$

11. How many old (pre-1982) cents are there in a pound? Your answer should be approximately 146. Show your work. What is the face value in dollars of this many cents?

$$\frac{\text{454 grams}}{\text{mass of each pre-1982 cent}} = \sim 146$$

$$\text{146 cents} \times \frac{\text{Cost calculated in Q3}}{\text{1 cent}}$$

12. What are the sources of error in this experiment?
    a. Uncertainty in the last digit of measurements
    b. Not letting the reaction go to completion
    c. Filing off the edges of the cent results in loss of some of the copper
    d. Assuming that only copper and zinc are present (no impurities)
    e. Assuming that the pre-1982 cent is 100% copper.

**Calculations with Moles**

Show all work and use units and the correct number of significant figures.

1. Calculate the moles of Cu in the post-1982 cent.

   Mass of Cu / Molar mass of Cu

2. Calculate the moles of Zn reacted.

   Mass of Zn / Molar mass of Zn

3. Calculate the atoms of Zn reacted.

   $$\text{Moles of Zn} \times \frac{6.02 \times 10^{23}\ \text{atoms of Zn}}{1\ \text{Mole of Zn}}$$

4. Calculate the moles of $H_2$ given off based on the zinc reacted.

   $$\frac{Zn}{H_2} = \frac{1\ \text{mole}}{1\ \text{mole}} = \frac{\text{moles of Zn calculated}}{x}$$

5. Calculate the volume of $H_2$ given off assuming STP conditions.

   $PV = nRT$

   Solve for V using n from Question 4.

   $$V = \frac{nRT}{P}$$

6. Calculate the molecules of $H_2$ given off.

$$\text{Moles of } H_2 \times \frac{6.02 \times 10^{23} \text{ molecules}}{1 \text{ mole of } H_2}$$

7. How many moles of hydrochloric acid were actually needed?

$$\frac{1 \text{ mole of Zn}}{2 \text{ moles of HCl}} = \frac{\text{moles of Zn from Question 2}}{x}$$

8. How many moles of HCl did you start with?

$$25 \text{ mL} \times \frac{1 \text{ Liter}}{1000 \text{ mL}} \times \frac{6 \text{ Moles}}{1 \text{ Liter}}$$

= 0.15 moles of HCl

9. How many post-1982 American cents would you need to react at STP with HCl to fill a room with Hydrogen gas if the room's dimensions are 12m long, 10 m wide, and 12.5 m high.

   12 m x 10 m x 12.5 m =1500 $m^3$ total area/volume of $H_2$ each cent produces (from Q 5)

10. Why do newer cents weigh less even though they are the same size as the old ones?

    Zinc has a lower density that copper.

How the Determination of the Value of a Copper Coating on a Post-1982 American Cent Laboratory Meets the Needs of all of Kolb's Learning Styles: Divergers, Assimilators, Convergers, and Accommodators