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Why do some students struggle while others succeed in chemistry? A study of the influence of undergraduate student beliefs, perceptions, and use of resources on performance in introductory chemistry




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# Why do some students struggle while others succeed in chemistry? A study of the influence of undergraduate student beliefs, perceptions, and use of resources on performance in introductory chemistry

By

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requirements for the degree of

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**Abstract**

Why do some students struggle while others succeed in chemistry? A study of the influence of undergraduate student beliefs, perceptions, and use of resources on performance in introductory chemistry

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This dissertation explores how student beliefs about the nature of science learning, beliefs in their academic ability, perceptions of the classroom environment, perceptions of external support, and use of resources contribute to success in introductory chemistry as measured by midterm and final exam scores. These factors were selected for study because they are susceptible to instructional intervention. A beliefs and perceptions survey and use of resources framework were developed, tested, and utilized to find predictors for student grades.

To measure beliefs and perceptions the Chemistry Beliefs and Perceptions Survey was developed and tested. A total of 428 introductory chemistry students responded to the survey measuring their beliefs and perceptions during Fall 2009. Factor analysis of student responses yielded four categories of beliefs and perceptions: nature of science learning, academic ability, classroom environment, and external support. A hierarchical linear model estimated the influence of student beliefs and perceptions on exam scores. There was a positive relationship between exam scores and (a) belief in academic ability and (b) belief that learning science involves understanding dynamic processes. There was a negative relationship between exam scores and perception of external support. Perceptions of the classroom environment were not strongly related to exam scores. These results were replicated with survey responses collected from students taking the course the following Fall (N=597).

To characterize student use of resources, a subset of survey participants (N=61) were interviewed at three time-points spanning the Fall 2009 semester. Interview responses were used to create a Use of Resources Framework. This framework described students as memorizers, procedural thinkers, critical thinkers, or researchers. Students characterized as memorizers or procedural thinkers view outside sources of information as the "authority," while critical thinkers and researchers evaluate information for themselves and generate explanations in their own words by using multiple relevant ideas. The four use of resource levels were shown to predict exam performance. There was a positive relationship between use of resources and exam performance.

Survey and interview measures were combined for the subset of 61 students to explore the joint contribution of use of resources along with beliefs and perceptions on exam performance. The influence of student beliefs in their academic ability on exam performance was found to be mediated by use of resources. That is, there was a positive relationship between belief in academic ability and use of resources. There was also a positive relationship between overall use of resources and exam performance.

To illustrate these relationships, three case studies are described. The case studies demonstrate the strong relationship between use of resources (for example the textbook, solving problems, interactions with peers) and understanding of chemistry as revealed on the exams. The cases illustrate how students use resources to understand the course material. Memorizers and procedural thinkers explain the idea of boiling based on connection of recalled information with little evaluation of these ideas. Critical thinkers and researchers explain their understanding in their own words, including evaluation of multiple explanations on the topic. These results suggest that it might be valuable to instruct students in productive ways to use resources so they can succeed in chemistry. This may be done by modeling effective strategies to become a more independent learner such as (a) evaluation or critique of information before accepting its accuracy, (b) translate information to create their own understanding, (c) work out problems on their own before confirming answers with others, (d) opportunities to exchange and evaluate ideas with others. Instructional interventions that improve student use of resources in chemistry could lead to better overall student performance.

## Dedication

To my parents, who encouraged my curiosity.

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# Chapter 1: Introduction and Research Questions

## Introduction

Technology and medical advances have enabled doctors nowadays to diagnose, manage, and treat more conditions than before. Nanotechnology is allowing doctors today to see increased details inside the body and perform surgeries with minimal invasion. The development of anti-rejection drugs has allowed for organ transplants and vaccines have reduced the incidents of many previously common diseases such as Polio or measles (http://www.cdc.gov/vaccines/vpd-vac/default.htm). Medical advances have resulted in an increased life expectancy and growing number of older people. As the average life expectancy continues to rise, more healthcare professionals are needed to meet the needs of an aging society. Employment of healthcare practitioners and technical occupations is expected to expand by 21 percent between 2008 and 2018, more than double the total expected increase in employment of 10 percent during the same period (http://www.bls.gov/oco/oco2003.htm).

A more diverse population will be needed to meet the growing demand for professionals in the medical field. Increased racial and ethnic diversity of the medical profession have been called for by both the Institute of Medicine (Smedley, Stith, Colburn, & Evans, 2001) and the Association of American Medical Colleges (http://www.aamc.org/factsandfigures). While the U.S. workforce is growing in diversity, medical professionals in the U.S. do not represent the nation's ethnic and racial diversity. Those of African American, Hispanic, or American Indian/Alaskan Native backgrounds are markedly underrepresented relative to their shares in the overall U.S. population (Alexander, Chen, & Grumbach, 2009).

Introductory chemistry courses are often seen as a substantial barrier to student participation in scientific careers, including medicine. “The principal reason given by students for their loss of interest in continuing as pre-meds was a negative experience in one or more chemistry courses” (Barr, Gonzalez, & Wanat, 2008, p. 503). Students who were losing interest in continuing as pre-meds cited chemistry four to five times more often than any other course. This was found to be true at both a small private and a large public university, suggesting that this issue is not specific to one type of institution (Barr, Matsui, Gonzalez, & Wanat, 2010). This link between a negative experience in a gateway course (such as introductory chemistry) and loss of interest in pursuing pre-med studies is particularly true among underrepresented minorities and female students (Gardner, Mason, & Matyas, 1989). Multiple researchers have called for reform of these introductory courses that “weed out” pre-med students (Alexander et al., 2009; Barr et al., 2010). Interventions designed for the undergraduate level to support students in these introductory courses may help to decrease the negative experiences students are reporting.

Why do some students struggle while others succeed in introductory chemistry? At the undergraduate level, many capable students, who have excelled in earlier science courses, find themselves struggling to grasp the concepts presented in introductory chemistry. Introductory chemistry is traditionally taught through large lecture courses in conjunction with a laboratory component. These lecture courses are often characterized as impersonal with pedagogy focusing on didactic delivery of material from the professor to the students. While focusing on algorithmic solutions to problems and individual concepts, traditional chemistry curriculum does not promote understanding of the concepts at the atomic level (Nakhleh & Mitchell, 1993).

This study focuses on a diverse group of students enrolled in introductory chemistry at a large public university. Instructors of this course have made extensive curricular modifications to help support students' development of conceptual understanding. The modifications were grounded in current curricular approaches shown to support students' development of scientific thinking (Chiu, Chou, & Liu, 2002; Hunt & Minstrell, 1994; Linn, Lee, Tinker, Husic, & Chiu, 2006; Levy & Wilensky, 2009; Pallant & Tinker, 2004; Teichert & Stacy, 2002; Tien, Teichert, & Rickey, 2007). The term "scientific thinking" in this study refers to the ability to use atomic level models and descriptions in explaining links between multiple phenomena in chemistry. Content was presented within a context that was familiar to students. Data were presented to students to allow for identification of patterns and explanations of theories based on observations. Students were provided multiple opportunities to participate and learn from each other. They were encouraged to generate and revise their own explanations, and evaluate their ideas. Yet, despite these modifications, instructors still reported that some students were struggling to succeed. While all students had the ability to succeed in chemistry, this study investigated how their beliefs, perceptions, and behavior influenced their level of success.

The students' beliefs, perceptions, and behavior selected for evaluation in this study are hypothesized to influence student success while also having the potential for intervention. While past experiences influencing success cannot be changed, the resultant beliefs, perceptions, and behavior selected for this study are believed to have the potential for change through course interventions.

The beliefs, perceptions, and behavior selected for this study are:

- *Beliefs about learning science* - defined for this study as the beliefs a student holds about the nature of science and what is involved in learning and understanding scientific concepts;

- *Beliefs in their academic ability* - defined for this study as a measure of a student's self concept or one's general opinion of the self in the domain of chemistry;

- *Perceptions of the classroom environment* - defined for this study as the perceptions a student has about the classroom in terms of his/ her interaction with peers and staff, the equity between students, as well as his /her level of allowed involvement compared with other students;

- *Perceptions of external support* - defined for this study as the perception or level of agreement a student has towards the idea that others (teachers, peers, family) believe in his/her ability to perform well in the course and support his/her decision to study at the college level; and

- *Use of resources* - defined for this study as the way a student uses available course resources when studying and learning. The available resources considered were: (1) text based resources such as the course textbook, lecture slides, or online information; ( 2) solving given problems from homework, the textbook, or past exams; and ( 3) peers or other social interactions towards studying such as office hours or organized study groups.

The overarching goal of this dissertation work was to understand the influence of these selected beliefs, perceptions, and behavior on the level of success a student had in the course. Survey and interview data were collected at three time points during the semester, allowing a longitudinal analysis. A mixed methods approach was utilized to allow for inclusion of both survey and interview responses. Survey data allowed for analysis of the influences these beliefs and perceptions had on success from a large population ($N_{2009}$=428; $N_{2010}$=597). Individual interviews with a representative sub-set of the population allowed for a more detailed exploration of behavior and conceptual understanding (N=61). The survey and interview data complemented each other since the survey responses gained insight from a large population on the effects of their beliefs and perceptions, and the interviews allowed for a more detailed understanding of the resultant behavior that may explain these relationships.

This study expands on the current literature in three ways. First, this study investigates the interaction of the selected beliefs and perceptions to test for confounding effects that may exist. Second, the analysis includes an evaluation of the beliefs and perceptions for their possible effects on student behavior in use of resources. If found to act as a mediator behavior in use of resources will help to explain why these beliefs and perceptions influence course performance. Third, this study is conducted among students who were being taught using a non-traditional curricular approach, focusing on the development of conceptual understanding. This allowed for the evaluation of how the selected beliefs, perceptions, and behavior, found previously to affect student performance in studies of traditionally taught classes, were still influencing students when using this modified curriculum. The findings will be used in future work to inform the design of embedded curricular interventions aimed at supporting students in using productive strategies to develop scientific thinking and promote effective use of the course resources.

**Research Questions**

The overarching research question for this dissertation is "What influence do student beliefs, perceptions, and behavior have on the development of scientific thinking in chemistry?" This dissertation outlines the development and use of survey items along with analysis of interview data. Survey data were used to measure student beliefs and perceptions. The interview data were used to characterize student behavior in use of resources and conceptual understanding of boiling and boiling points for different chemical substances. Through this research the following research questions are addressed:

1. How do student beliefs about learning science, beliefs about their academic abilities, perceptions of the classroom environment, and perceptions of external support affect course performance?

Together chapters 4 and 5 outline development and use of the necessary measurement instrument to find the answer to the first research question. The steps taken in developing reliable items for use in collecting survey measures on the selected beliefs and perceptions are outlined in Chapter 4. Chapter 5 employs a hierarchical linear model approach to analyze the measures collected from responses to survey items to answer the first research question.

2. What study strategies do students demonstrate when using resources for the course and which behaviors prove most successful in developing scientific thinking?

Chapter 6 describes the development of the Use of Resources Framework outlining the common approaches students take in their use of resources within the context of an introductory chemistry course. This framework characterizes the behaviors students exhibited towards use of resources. Evaluation of the Use of Resources Framework was carried out by testing the ability to distinguish exam performance between students in each Use of Resource level defined. Chapter 6 utilizes the framework developed to evaluate use of resource level's ability to distinguish exam performance and answers the second research question.

3. How do beliefs and perceptions impact student behavior towards use of resources and student course performance?

Chapter 7 explores the influence the selected beliefs and perceptions have on student use of resources, as well as the effect that the use of resource behavior has on course performance. This answers the third research question and determines if student use of resources mediates the effects found in the first research question.

4. Does student use of resources correlate with understanding of chemistry concepts or development of scientific thinking in introductory chemistry?

Chapter 8 details an in-depth analysis of three case studies used to answer this fourth research question. These three case study interviews were chosen to represent the main behaviors characterized by the Use of Resources Framework. Scientific thinking was assessed based on student responses in these case studies on questions exploring their understanding of boiling points.

## Chapter 2: Rationale

This research aims to understand the influence of selected beliefs, perceptions, and behavior on student's development of scientific thinking in chemistry. This chapter provides an overview of the literature used to shape the decisions behind this research and the possible influence each of the selected beliefs and perceptions have on student performance. Before evaluating possible influences on development of scientific thinking, the proposed method for developing scientific thinking must first be understood. The knowledge integration perspective is used to explain the process of developing scientific thinking. An explanation of the link between knowledge integration and the term scientific thinking as defined by this study is highlighted. This is followed by a review of the current research on the selected beliefs and perceptions used in this study.

### Developing Scientific Thinking in Chemistry: A Knowledge Integration Perspective

How does a student come to use the ideas presented in science classrooms to explain scientific phenomena? How do they develop an understanding of what they observe in the world using scientific principles or theories? These are the types of questions that were being addressed when thinking about the influences on development of scientific thinking in chemistry for this study. As stated in the introduction, the term "scientific thinking" in this study refers to the ability of a student to use atomic level models and descriptions in explaining links between multiple phenomena in chemistry. To guide this effort, this research used the Knowledge Integration Learning Perspective (Linn, 2006).

Knowledge Integration found its roots in the growing themes identified through review of research in developmental, socio-cultural, cognitive, and constructivist perspectives (Linn & Eylon, 2006). The formulation of the knowledge integration perspective resulted from studies of students working to generate a coherent explanation by resolving conflicting ideas. The knowledge integration perspective characterized learners as "developing a repertoire of ideas, adding new ideas from instruction, experience, or social interactions, sorting out these ideas in varied contexts, making connections among ideas at multiple levels of analysis, developing more and more nuanced criteria for evaluating ideas, and formulating an increasingly linked set of views about any phenomena" (Linn, 2006, p. 243). The definition of scientific thinking in this study is consistent with this view of learning as a process of identifying, linking, and evaluating related ideas to explain scientific phenomena. The term scientific thinking in this study is more specific to chemistry since it specifies the inclusion of atomic level models and descriptions in the formation of links to create an understanding of related phenomena.

At the classroom level, many studies have shown evidence to support a link between instructional approaches and development of scientific thinking (Chiu, Chou, & Liu, 2002; Hunt & Minstrell, 1994; Levy & Wilensky, 2009; Linn, Lee, Tinker, Husic, & Chiu, 2006; Pallant & Tinker, 2004; Teichert & Stacy, 2002; Tien, Teichert, & Rickey, 2007). Linn and Clancy (1992) investigated the role of instruction on knowledge integration through classroom observations and interviews. In these studies, Linn and

Clancy (1992) found that students struggling in introductory college courses often believe they should be able to solve problems without encountering dead ends or wrong paths. In an attempt to change this view, instruction was implemented in a computer science course which emphasized students having to select among multiple alternative solutions to a complex problem. Stemming from this research on the role of instruction, Linn, Davis, and Eylon (2004) developed four meta-principles to help guide instructors and curriculum developers. These four meta-principles are: (1) making science accessible (presenting material within a context that is familiar to students); (2) making thinking visible (explicitly model the process of scientific thinking for students and allow students opportunity to model their own thinking for others); (3) help students learn from others (encourage productive interactions between students to build new understanding through sharing of each others ideas); and (4) promote autonomy and lifelong learning (include strategies to help students guide their own learning). Scientific thinking in this study is consistent with the goals of knowledge integration, with more specificity to chemistry. Given their similarity, it is hypothesized that these four key components outlined by Linn et al. (2004) can be applied to promote the development of scientific thinking. Chapter 3 outlines in detail how the modified curriculum used in this study incorporates these four meta-principles of knowledge integration for instruction.

Students bring with them a variety of experiences from their past. These experiences generate existing ideas that students bring with them into the classroom. The knowledge integration perspective allows students to include their existing ideas by eliciting these diverse and often conflicting ideas and incorporating them with new ideas presented in the course (Linn & Eylon, 2006; Songer & Linn, 2006). Knowledge integration engages students to use evidence in evaluating their existing ideas, along with new ideas from the course, to generate explanations incorporating multiple ideas. The knowledge integration perspective recognizes the diversity of student backgrounds and the many contexts students may have experienced prior to instruction on a subject. The goal of knowledge integration is not to isolate ideas in one context or another; rather it encourages students to make connections across contexts (Linn & Hsi, 2000). While some students may enter college with a rich array of experiences to draw from, others may be more limited in the experiences they have prior to starting college. This situation creates a difficulty for instructors since they do not know what experiences may be most influential on their students' learning in introductory chemistry. Students with limited experiences bring with them fewer ideas to draw from in forming connections with what they are now learning. The more experiences students have, the more ideas they have to draw from when making links to explain phenomena.

This research explores the influence of selected beliefs, perceptions, and behavior shaped by previous experiences on the development of scientific thinking. Because of its inclusion of students' existing ideas from previous experiences and guiding principles for instruction, the knowledge integration perspective was used in this research. Given the wide array of possible experiences that students may have, it was considered unreasonable to attempt to capture them all in this study. Instead, their effects were considered through selected student beliefs, perceptions, and behavior. A review of literature discussing student beliefs and perceptions selected for this study are presented below.

**Beliefs about learning science**

While some students view science as memorization of a set of facts (static), others believe that learning science requires understanding how scientific concepts are interconnected and how linking these different concepts can explain an observed phenomena (dynamic). From their review of the history of science, Songer and Linn (1991) conclude that science is a dynamic and socially constructed set of ideas. Memorization is not likely to lead to a deep understanding of either the nature of science or science concepts. This leads to the conclusion that a dynamic view of science will more likely lead to a deeper understanding of scientific concepts. In this dynamic view, students are integrating multiple events or observations and developing explanations that incorporate multiple ideas. Many studies following Songer and Linn (1991) have found evidence to support the original hypothesis that a more dynamic view of science leads to a deeper understanding of the content (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Rosenberg, Hammer, & Phelan, 2006; Stathopoulous & Vosniadou, 2007).

Rosenberg et al. (2006) suggest that students express different beliefs about learning science depending on the classroom context. Dialogue between students discussing the rock-cycle showed a shift in their beliefs following an intervention from the teacher. The teacher's advice of a simple phrase "start with what you know, not with what the paper says" (p. 272) cued the students into a different learning context. This proved successful in switching students working in a group from the use of terms and facts to the use of scientific logic to explain the rock cycle (Rosenberg et al., 2006). Alternate analysis of this classroom dialogue showed further support for the hypothesis that students held multiple beliefs about learning science, and that their beliefs were not well characterized in a single dimension of development (Hammer, 1994). Rosenberg et. al., (2006) argue that "findings of coherent epistemologies in the literature may result from the particular context of the studies, questionnaires, surveys, interviews, and clinical observations" (p. 288). The influence classroom instruction has on students' expressed beliefs about learning science are demonstrated by the findings of Rosenberg et al., (2006). To extrapolate from these findings: previous instruction, or experiences with science, may influence the beliefs about learning science held by students entering introductory college chemistry. The influence from these previous instructions or experiences is captured in this current study through measuring the resultant student beliefs about learning science.

**Beliefs about their academic abilities**

Measures of both self-efficacy and self-concept have been used to evaluate the predictive powers of beliefs about academic ability on course performance in chemistry (Britner & Pajares, 2006; House, 1995; Nieswandt, 2007). While self-efficacy is less concerned with what skills an individual possesses and more on their expectations and convictions of what can be accomplished in given situations, self-concept represents one's general perceptions of the self in a given domain (Bong & Skaalvik, 2003). This study focuses on measuring a student's self-concept in chemistry. House (1995) found that compared with ACT scores and number of mathematics courses taken, initial attitudes of performance or self-concept in chemistry was a better predictor of college chemistry performance (House, 1995). Nieswandt (2007) found similar effects of self-concept when studying high school students learning chemistry. Nieswandt (2007) measured a student's situational interest, attitudes towards chemistry, and chemistry-specific self-concept at two time points: the middle and end of semester. Nieswandt (2007) found evidence that earlier self-concept acted as a mediator along with situational interest to influence later self-concept. This later self-concept had a positive effect on conceptual understanding in chemistry (Nieswandt, 2007). These studies outline instruments to measure self-concept, as well as report the positive relationship they find between self-concept and course performance in chemistry (House, 1995; Nieswandt, 2007).

Studies focusing on the measurement of self-concept use items which direct the attention of respondents toward their future expectancies in a course or general perception of a given subject. It is suggested that beliefs of this nature may have been shaped by past experiences with the subject or social interactions with individuals related to the subject (Britner & Pajares, 2006). This is important because students entering the introductory chemistry course are primarily first year college students. Self-concept is a more appropriate measure than self-efficacy for this population because they have not yet accurately assessed the demands of the course during the first week. They may not have a well-developed understanding of the expectations in a college level chemistry course. The influence from past experiences either with the subject matter or individuals associated with the chemistry domain is captured in the current study by the measurement of the resultant student self-concept in chemistry.

**Perceptions of the classroom environment**

Some classroom environments have been attributed to invoking stereotype threat situations for students that belong to vulnerable groups, namely, underrepresented minorities and females. The Stereotype Threat model (Steele & Aronson, 1995) posits that, when individuals from a group perform a task in an area in which the group is considered weak (based on group stereotypes), they feel at risk of confirming the stereotype, and psychological pressure will lead them to underperform. When the members of a group can be negatively stereotyped in a social situation, they carry an extra burden; their performance, good or bad, might well be interpreted in terms of the prevailing racial or gender stereotype (Spencer, Steele, & Quinn, 1999). Should the performance be consistent with the stereotype (e.g., a woman scoring poorly on a math test, an upper class white man being clumsy on the dance floor, etc.), the behavior serves to confirm the stereotype in the eyes of the beholders. A recent study of performance differences on a test of special reasoning showed that when primed towards either their identity as a student at an elite university or their gender category, participants showed differences in performance (McGlone & Aronson, 2006). Their findings show that the possibility of attaining additional identities that have positive expectations through priming may improve exam performance for groups who were previously at risk of threat.

At the university level, experiences in the classroom have been found to influence the development of relationships between teachers and students as well as among the students (Eames & Stewart, 2008). The nurturing of these relationships are reported to be valued by staff and students, thus, there is a need for consideration towards fostering these relationships within classrooms (Cronje & Coll, 2008). These findings support those found in the area of stereotype threat that advocate creating a more supportive learning community. There is a possibility that creating a more supportive learning community would produce alternate, more positive identities, with which students could associate (McGlone & Aronson, 2006).

The findings on environmental perceptions highlight two things. First is the importance of evaluating how students perceive the classroom. Second is the importance of evaluating perception differences between groups of students. A measure of student initial perception of the classroom environment will include effects from previous priming that influence how they interpret the current environment. The influence from previous priming or current classroom issues is captured in the current study by the measurement of student perception of the classroom environment.

**Perceptions of external support**

There are few studies on the influence of family or external support on academic achievement at the university level. A review of the current literature on family involvement and support indicates their positive impact on student achievement. However, these studies are overwhelmingly focused at the elementary and secondary school levels. Roman, Cuestas, and Fenollar (2008) found that family support increased academic achievement at the university level. These findings expanded on previous research by demonstrating the importance of parents' expectations and college plans for children over other outside support. Studies of support in higher education have traditionally focused on financial and university-led support systems, and excluded the notion of outside support structures. By focusing less on this traditional deficit model, some recent studies have looked into support at the university level from a new angle. The new angle concentrates around non university-led support not traditionally considered. Jacklin and Le Riche's (2009) study focused on the more open-ended question of what students found helpful within the university system. This approach has shown interesting findings of what students considered supportive. The main sources of support reported by students were peers and family. Previous findings from similarly structured interviews with students demonstrated the importance of friends and family to students (Robinson, Le Riche, & Jacklin, 2007). These studies also show how classroom and instructional aspects can influence the development of these social supports (Wilcox, Winn, & Fyvie-Gauld, 2005). Given these findings that demonstrate the importance of external support structures for students in a variety of majors, it is likely that the same effects hold true in introductory chemistry courses. These findings are part of an initial step in evaluating the effects of family support in this study, and they provide motivation for further exploration into the topic.

This study focused on measuring the extent to which a student perceives to have external sources of support rather than the traditional university-led supports. This focus was based on the importance expressed by students towards family- and peer- based support indicated in the current literature. These expectations from parents and other individuals are not novel to a student entering college.  These expectations have been set previously, and have influenced their choices to continue their education at the college level. Perceptions of their support system include previously set expectations even as their peer group and other relations evolve as they transition into college life. Expectations and feelings that a student carries with him/her into college as well as the present experiences are captured by the measured effects of external support on a student's academic achievement.

## Chapter 3: Framing: Structure of the course

Introductory chemistry at the university level is traditionally taught through large lecture courses in conjunction with a laboratory component. These lecture courses are often characterized as impersonal with pedagogy focusing on didactic delivery of material from the professor to the students. While focusing on algorithmic solutions to problems and individual concepts, traditional chemistry curriculum does not promote understanding of the concepts at the atomic level (Nakhleh & Mitchell, 1993). Given the difficulty students currently have with the subject, there is a need to modify the traditional didactic approach. Changes have been made in the introductory chemistry course used for this research to provide a more student-centered and conceptual approach to learning.

The modified curriculum used was developed over the course of several semesters with the following guiding principles or goals:

- present material for each unit within a context that is familiar to students;
- present data that allows for students to discover the underlying patterns and use this knowledge as the basis for explaining the theories developed;
- model the process of scientific thinking through the lessons; and
- provide opportunities for students to
    - participate and learn from each other; and
    - generate explanations, evaluate their ideas, and revise these explanations.

The following provides an overview of the course structure, highlighting the key components. The course has been divided into four curricular units: matter, change, energy, and quantum. Each of these units is presented with a unifying context that is familiar to students' lives. Before each lecture, students are provided with a "pre-class" assignment, designed in a way that can be completed without the use of the textbook. Students are presented with a set of data or directed to a dynamic visualization and then guided to explore the trends or make observations about what is being presented. These assignments help orient the students to the upcoming material by scaffolding exploration of relevant data or simulations. The material in the lecture integrates demonstrations and dynamic visualizations to help students connect what is happening at the atomic level with the observable macroscopic level. The professor presents "quiz questions" during the lecture which have predetermined response choices. Students key in their responses to these questions through an individual response system (i-clicker). The system allows the professor to display the frequency of response choices from the class responses. If the responses indicate that students are still confused with a concept, they are given time to discuss the question with others seated around them and then "vote" again for their response choice.

Students are concurrently enrolled in a weekly four-hour discussion/laboratory section led by a graduate student instructor (GSI). These sections of approximately 30 students provide time for a more personal interaction between the students and the GSI. The section has a one-hour discussion component, which utilizes a discussion manual. The discussion manual guides students in explaining and evaluating their own ideas together with the other students. Through these exchanges students collaboratively generate a more robust and complete understanding of the concepts. This discussion is coupled with a three hour lab time where they further explore the concepts through experiments. Additionally, the graduate student instructor's have office hours that are open to all students in the course to provide them with additional opportunities to ask questions and receive feedback.

Exams in the course have been structured to focus largely on conceptual understanding. These include 15 multiple-choice questions, some of which have multiple possible answers. Students are challenged to distinguish the BEST answer. The multiple-choice questions are followed by a series of short-answer questions. Many of these items require the students to make connections between multiple concepts which have been presented in class through applying these in novel situations. In turn, the short-answer questions encourage students to not just memorize individual facts, but to make connections between ideas in the course and to understand their underlying theories.

The components of this modified curriculum for introductory chemistry are aligned with the Knowledge Integration Framework for Instruction (Linn, Davis, & Eylon, 2004). The Knowledge Integration Framework outlines four meta-principles, which are considered to be key instructional components in developing science curriculum. The four meta-principles are (1) make science accessible; (2) make thinking visible; (3) help students learn from others; and (4) promote autonomy and lifelong learning. The next few paragraphs of this section will outline the alignment of the modified curriculum with the Knowledge Integration Framework for Instruction.

First, making science accessible refers to designing materials that connect to the students' ideas and are relevant to their lives. The modified curriculum, unifying the content of each curricular unit through a context that is familiar to students, makes science accessible for students.

Second, making thinking visible refers to both the instructor's thinking and the students' ideas. On the one hand, it requires the instructor to model the process of scientific thinking through the lesson, making scientific thinking visible to the students. On the other hand, the instructor must also allow opportunities for students to make their thinking visible to help guide the instruction. When the instructor presents data and then models how this can be used to provide evidence for the given theories, the instructor facilitates the learning of the students by modeling scientific thinking in an observable way. The use of a classroom response system, allowing students to electronically "vote" for their answer to the given questions, and encouraging student questions and comments during lecture, makes the students' thinking visible to the instructor.

Third, helping students learn from others can be accomplished through class discussions, peer collaboration, or other peer interactions where students are able to build from each others ideas. These activities allow students to form a more robust understanding by using the collective knowledge of the group. Students are given time during lecture to discuss concepts with fellow learners. The sessions are structured so students explore ideas by explaining their thoughts to their group, evaluating the ideas of others, and combining these concepts to collectively build an understanding.

Finally, promoting autonomy and lifelong learning, refers to including the strategies to help students guide their own learning, and actively evaluate and critique new ideas they are presented with for accuracy. Pre-class assignments, highlighting patterns and allowing students time to explore visuals before presentation in class, allow them the opportunity to make predictions and evaluate these as they incorporate more ideas. These activities aid in promoting autonomy in learning as well as creating lifelong learners. The expectation of the course, to promote the generation of connections between concepts, is reinforced by the exams which are designed with conceptual short-answer questions. These questions are not meant to be tricky but would require the students to apply the concepts they have learned to novel situations and to evaluate the outcome.

These course components focus on creating students who are critical thinkers and adept at making connections between the concepts presented in the course. Students become more capable of connecting the material when multiple opportunities to form predictions, evaluate ideas, and refine explanations are provided. This ability to connect related ideas, presented within the course, and to use them to explain the world around them, as well as and the products they use in their lives, is the main learning outcome of the modified curriculum.

## Chapter 4: Development of Chemistry Beliefs and Perceptions Survey Instrument

### Introduction

To answer the first research question, a survey instrument was developed to collect measures of the desired beliefs and perceptions from students enrolled in introductory chemistry. The Chemistry Beliefs and Perceptions Survey was developed to collect measures of student:

1) beliefs about learning science;
2) beliefs about their academic abilities;
3) perceptions of the classroom environment; and
4) perceptions of external support.

The measures collected from the final survey instrument were used to answer the first research question "How do student beliefs about learning science, beliefs about their academic abilities, perceptions of the classroom environment, and perceptions of external support, affect course performance?" The analysis of measures collected by the Chemistry Beliefs and Perceptions Survey answering the first research question is described in Chapter 5. Together, Chapters 4 and 5 develop the necessary measurement instrument, analyze student responses, and find the answer to the first research question. The development of the Chemistry Beliefs and Perceptions Survey, including item refinement, lessons learned, and a summary of final items created, is described in this chapter.

### Rationale

Numerous surveys have been developed to find the answers to related questions, which helped to inform the original survey design. In the physical sciences three well known surveys are the Chemistry Expectations Survey (CHEMX), which is based on the Maryland Physics Expectations Survey (MPEX), and the Epistemological Beliefs Assessment about Physical Science (EBAPS) (Grove & Lowery Bretz, 2007; Elby, n.d.). While these surveys are informative, none of them include measures for all four of the selected beliefs and perceptions. They primarily focus on evaluating student belief about learning science and expectations related to learning chemistry. Measures from these surveys have not directly been used to correlate with student course performance. Instead they have been utilized to evaluate differences in beliefs or expectations between student and instructor (Grove & Lowery Bretz, 2007). While these surveys have not directly been used to correlate with student performance or development of scientific thinking in chemistry at the university level, they were helpful in this thesis for the item development of the survey. This study used the lessons learned in writing items from these studies to inform the current survey design. Extending the current literature, this study develops a single survey instrument to measure each of these beliefs and perceptions in a chemistry classroom.

In deciding to measure the selected beliefs and perceptions through a survey instrument, literature on each of these was reviewed. This review focused on studies describing how measures had been best captured previously and on issues identified with the development of survey items for each belief and perception. While this effort began with a survey measuring a wider range of beliefs and perceptions, the sections below outline the literature informing the measurement of the final selection of beliefs and perceptions.

*Beliefs About Learning Science*

Measurement of student beliefs about learning science is not straightforward. For example, Songer and Linn (1991) found from analyses of student responses to the Views of Science Evaluation items that only nine items gave valid, varied responses. Designing items to elicit a range of valid responses proved to be difficult. Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) claimed additional interesting results from students answering more open-ended items on the nature of science. Taking a different approach, Hammer (1994) analyzed case studies of students solving problems and answering indirect questions about how their science course was going. When asked to solve problems and provide explanations to questions, students revealed their beliefs both explicitly and implicitly through their comments and actions. Rosenberg, Hammer, and Phelan's (2006) analysis of classroom dialogue between students demonstrated a shift in students expressed beliefs based on the context of classroom instruction. While these studies agree with the basic overall categorization of static versus dynamic, they disagree in the methods used to capture student beliefs. Rosenberg et al., (2006) argue for analysis of student learning of the content. Others utilize open-ended or survey type items related to the nature of science that can illuminate student beliefs (Lederman et al., 2002; Songer & Linn, 1991; Stathopoulous & Vosniadou, 2007).

Considering these findings and the affordances found with different measurement methods, this study attempts to develop Likert style survey items to capture student beliefs about learning science. While analysis of individual student interviews would provide a deeper understanding of student beliefs about learning science, the researcher did not want to restrict the sample size to this degree. The development of survey items avoided limiting the sample to a small representative sub-set of the class who could be interviewed. Being aware of the issues previously found in measuring beliefs about learning science, this study gave careful consideration to the phrasing of survey items and the context they may trigger for the respondent. Analysis was critical of how the developed Likert style items grouped together based on factor analysis of student responses. This was done to ensure the desired belief or perception was being captured.

*Beliefs About Their Academic Abilities*

Beliefs about one's academic ability in chemistry can be defined as chemistry self-efficacy, or chemistry self-concept. Previous studies have reported instruments to measure each of these beliefs and their findings of the relationship of these beliefs with performance (House, 1995; Nieswandt, 2007). While self-efficacy is less concerned with what skills an individual possesses and more on his/her expectations and convictions of what can be accomplished in given situations, self-concept represents one's general perceptions of the self in a given domain (Bong & Skaalvik, 2003). Items designed to measure self-concept focus more on asking the respondent about his/her perception of a given subject. Self-efficacy items ask the respondent to rate how well he/she will perform on a specific task. When constructing measurement items of self-concept it is critical to consider the close relationship between these two concepts, self-concept and self-efficacy.

Items constructed by Bong and Skaalvik (2003) were used as a guide in this study to measure student self-concept in chemistry through Likert style survey items. To ensure items were capturing self-concept in chemistry, most items included the wording "in this course" or reference to the domain chemistry. The current study focuses on measurement of self-concept instead of self-efficacy since self-concept items tend to direct the attention of respondents toward their past accomplishments. Self-efficacy items focus the attention of students on their future expectancies. This is important because students entering the course of focus in this study are primarily first year college students. They may not have a well-developed understanding of the expectations in a college level chemistry course. Self-concept is a more appropriate measure for this population given that students have not had time to accurately assess the demands of the course during the first week of the semester, when they are initially surveyed.

*Perceptions of the Classroom Environment*

Perception of the classroom environment is difficult to measure since many of the methods designed to capture it have themselves been linked with impacting performance (McGlone & Aronson, 2006). Studies focusing on the issue of stereotype threat have many times primed students towards their identity in a specific group. Evaluation of the effect due to stereotype threat is determined by comparison of exam performance between groups of students who had been primed with those who had not been primed (McGlone & Aronson, 2006; Spencer, Steele, & Quinn, 1999). Ali, Rohindra, and Coll (2008) explored the question of how students perceive interactions between themselves and others within a given course. This was done through analysis of student responses to the *actual* and *preferred* versions of a learning environment instrument using the *What is Happening in This Classroom* (WIHIC) survey in a multi-cultural university-level environment. This analysis further allowed for exploration of differences in perceptions between cultural groups in a class. The items used in the WIHIC survey suggest a link between the differences in the minority students' perception of equity and involvement in the classroom and their lower achievement.

Not wanting to negatively impact student performance in the course, this study aimed to measure the influence of perception of the classroom environment with minimal risk of priming. Two methods, Likert style items and a ranking selection, were used to capture this perception. This study used Likert style items based on those developed for the *What is Happening in This Classroom* (WIHIC) survey (Ali et al., 2008). Student focus groups were used to inform the development of choices for ranking in terms of perceived impact on course performance. This ranking of choices was used to determine if a student chose classroom-based concerns over other choices. To minimize the risk of impacting performance through priming, responses to items were collected through surveys administered separately from other course assignments. This was done to minimize students association of responses to these items with a specific task or exam in the course.

*Perceptions of External Support*

Some recent research has considered support at the university level from a new angle, focusing less on this traditional deficit model. Jacklin and Le Riche's (2009) study centered on the more open-ended question of what students found helpful within the university system. This approach has shown interesting findings about what students considered supportive. The main source of support reported by students was peers and family. Previous findings from similarly structured interviews among similar groups demonstrated the importance of friends and family to students (Robinson, Le Riche, & Jacklin, 2007) and how classroom and instructional aspects can influence the development of these social supports (Wilcox, Winn, & Fyvie-Gauld, 2005).

While previous studies have used open-ended items or interview responses (Jacklin & Le Riche, 2009; Robinson et al., 2007) Likert style items were created for use to allow for a larger response population. Interviews or other more open-ended type of collection would have restricted the sample size. These Likert style items on the survey allowed for all students to have the opportunity to respond. Survey items included in the current study aimed to replicate these prior findings, and expanded on this non-traditional consideration of support at the university level. Since college level students do not typically live with their families, and families are not always defined in the traditional sense, the items were constructed to relate to the students' perception of available network of support. This study expands the idea of family support into "external support" by including friends, other relatives, or mentors that students go to for support.

*Design Hypothesis*

Based on previous survey findings as well as literature specific to each belief and perception, the following hypothesis informed the design of items: Writing items using the following three criteria will produce reliable measures for capturing the beliefs and perceptions of each respondent:

1) ensure clear and concise wording to minimize multiple interpretations;
2) use language that is consistent with students use and knowledge; and
3) relate each item specifically to the chemistry course to lessen the inclusion of related beliefs or opinions towards science as a more general subject.

## Methods

To measure student beliefs and perceptions at multiple time points spanning the semester, this study developed a collection of surveys. Survey administration happened at the beginning, midpoint, and end of the semester. The surveys included items measuring student: (1) beliefs about learning science; (2) beliefs about their academic abilities; (3) perceptions of the classroom environment; (4) perceptions of external support; and (5) demographic information. Survey items were developed through pilot testing and focus group interviews over six semesters. A description is given below as to how each phase, or semester, influenced the development of the current survey instruments. The final surveys used for measurement of student beliefs and perceptions were administered during Fall 2009 and Fall 2010. The Fall 2010 version expands on the measures collected with the 2009 version to include a new method to measure perception of the classroom environment.

**Participants**
Participants were students enrolled in the introductory chemistry course at a large public university. This course enrolls approximately 1300 students each Fall semester. This course is designed for non-chemistry majors who need to take chemistry as a pre-med or major requirement.

**Survey Development and Collection**
*Phase 1 (Fall 2008)*
The original survey included a variety of topics and question formats to pilot various influences cited in the literature. This survey contained items attempting to measure currently included beliefs, and perceptions, along with items capturing information about students living situations and extracurricular or family commitments.

During the first week of instruction, students were asked to complete the Chemistry Beliefs and Perceptions Survey administered through an online survey site (surveymonkey.com). At the midpoint of the semester and in the last week of class, students were asked to complete follow-up surveys including items from the first survey as well as questions about study habits, use of course materials, and other aspects of the course. Survey responses were collected from all students in the course who consented to participate. Student responses to Likert style items were grouped based on findings from factor analysis of item responses. Student survey measures were then matched with course exam grades for analysis. Regression analysis found effects between some of the measures of student beliefs and perceptions, and exam grades. This preliminary data analysis identified issues pertaining to the structure of certain items as well as the overall survey design. The analysis also allowed for elimination of items relating to variables for areas which did not demonstrate significant effects on exam grades. It was then decided that for some variables, while they did affect student exam performance, instructors did not have any authority to intervene and help on these issues. The focus was constrained using these three criteria to select beliefs and perceptions: (1) shaped by students prior experiences; (2) found previously to effect student performance; and (3) instructors had the capacity to intervene. This focus led to survey refinement for use in Phase 2.

*Phase 2 (Spring 2009)*
As in Phase 1, students were asked to complete online surveys (revised from Phase 1) at three time points in the semester. In addition, student focus groups were conducted. Two focus groups were led to elicit student interpretation of the survey items, facilitate item clarity, and collect their perception of factors influencing their course performance. The evaluation of which beliefs and perceptions show the most significant effect was based on feedback from focus groups. Concurrently, responses to the surveys were again correlated with exam scores. Regression analysis was performed on student responses and exam scores along with factor analysis of Likert scale questions. After quantitative analysis and integration of focus group findings, further revision of the items and overall survey design was done. The number of items was reduced to focus on the beliefs and perceptions that seemed most influential to students in the course and could provide the best opportunity for intervention.

*Phase 3 (Summer 2009)*
The revised version, from Phase 2, of the survey was administered again. Due to the altered pace of the summer session, only the first of the three surveys was administered. Factor analysis was performed on the Likert scale items to ensure they were factoring as expected. Based on this factor analysis, final revisions were made to the items before use in Fall 2009.

*Phase 4 (Fall 2009)*
As done in Phases 1 and 2, all students were asked to complete the Chemistry Beliefs and Perceptions Survey (revised from Phase 3) during the first week of instruction. Midway through the course, students who consented to participate were asked to complete a second online survey administered in the same way. This survey, along with collecting repeated and additional measures of students beliefs and perceptions, asked questions relating to their use of course materials and study strategies. It also included questions relating to how students might have changed their study strategies between the first and second exam. The final survey was administered at the end of the course collecting responses to repeated items from earlier surveys in the semester along with questions about their use of course materials and any changes since the mid-semester survey.

*Phase 5 (Spring 2010)*
The survey was further revised to include an additional method to measure the student perceptions of the classroom environment. The new items to measure student perceptions of the classroom environment, were modeled after those used to measure the equity, involvement, and support scales within the *What is Happening in This Classroom* (WIHIC) survey (Ali et. al., 2008). These new items were tested during the Spring 2010 semester, and those that were found to factor well into the desired categories were administered during survey collection in Fall 2010.

*Phase 6 (Fall 2010)*
As in the previous semesters, students were asked to complete the Chemistry Beliefs and Perceptions Survey online during the first week of instruction. They were also prompted to complete follow-up surveys at the midpoint and end of the semester. The Fall 2010 version of the survey was administered to collect student responses for confirmatory analysis. Students perceptions of the classroom environment based on items revised during Phase 5 were collected to determine any differences of this perception based on this new measurement.

**Analysis**
Likert style items were grouped based on factor analysis findings. Factor loadings are a measure of the strength of association between the responses and the belief or perception they are measuring. Student responses for items that were worded in the reverse (negative) of the desired belief or perception were coded to indicate students' disagreement with the item (reverse coded). In this study, a factor loading cutoff of 0.3 or above was used. Responses to these grouped items were then averaged to create a single measure for each of the student beliefs and perceptions: (1) belief about learning science (Fall 2009 version only); (2) belief about their academic abilities; (3) perception

of external support; and (4) perception of the classroom environment (Fall 2010 version only). Cronbach's alpha reliability coefficients were computed for each of the belief or perception measures created from these Likert style items. Cronbach's alpha is a commonly used measure of the internal consistency or reliability of items representing the extent to which a group of items used within a survey to represent a given dimension are actually measuring the same dimension. A Cronbach's alpha of above 0.70 may be considered acceptable for education measurement instruments (Wiersma & Jurs, 2005). Perception of the classroom environment was also captured through items created from focus group findings. Responses to these items were used to create a dichotomous dummy variable representing whether the student indicated a concern for the classroom environment or not.

**Results**

The final survey versions used during Fall 2009 and Fall 2010 included items to measure student: (1) beliefs about their academic abilities, (2) perceptions of the classroom environment; (3) perceptions of external support; and (4) student demographics. A measure for student beliefs about learning science was collected from items used on the Fall 2009 survey version, but these items were excluded for the Fall 2010 version. Measures of students' use of course resources were also collected as part of these surveys, yet it is still not determined how to best measure this. Table 1 outlines when each of these beliefs and perceptions were measured and how.

**Table 1: Summary of item types used to measure each belief and perception in final survey versions**

| | Measurement | Source |
|---|---|---|
| Belief about Learning Science | • Likert style items | • Fall 2009<br>Survey 1, 2, & 3 |
| Belief about Academic Ability | • Likert style items to capture student chemistry self-concept | • Fall 2009/2010<br>Survey 1, 2, & 3 |
| Perception of the Classroom Environment | • Student selection of "top 3 concerns" from predetermined list<br><br>• WIHIC based Likert style items to capture student view of their classes "equity" -Ali, Rohindra, & Coll, 2008 | • Fall 2009/2010<br>Survey 1<br><br>• Fall 2010<br>Survey 2 & 3 |
| Perception of External Support Structures | • Likert style items | • Fall 2009/2010<br>Survey 1, 2 & 3 |

While these do not represent all of the items administered within each of these surveys, Table 1 outlines those that were found reliable for measurement of each of these beliefs and perceptions. Below outlines the process of item development, analysis of reliability, some of the issues identified, and final items used for measuring each of the beliefs and perceptions. A complete list of Likert items administered for each survey is given in Appendix A.

*Beliefs About Learning Science*

Initially, items attempting to measure student beliefs about learning science were constructed similarly to the Epistemological Beliefs Assessment about Physical Science (EBAPS). Items were modified to reflect a focus specifically on chemistry. The main issue, identified with these types of items during focus groups with students in Spring 2009, was the items' ambiguity or inability to measure the belief we had defined. For example a statement such as "science is just a lot of facts that you need to memorize" may at first reading seem to imply a very different view of learning science than the statement "science is not just facts to memorize independently, they relate to each other". However students were found to often times agree with both statements equally, explaining that they needed to first memorize all the facts, and then memorize how they connected ideas to explain things.

These types of explanations from students and the realization of how many interpretations were possible made the measurement of this belief very difficult. Due to the high degree of students misinterpreting the items during focus group interviews and previous literature findings stating difficulty in measuring student beliefs from survey items (Songer and Linn, 1991), these items were only used during the Fall 2009 collection for analysis. These items were included during Fall 2009 to explore possible effects but were excluded during Fall 2010 due to concern over their interpretation.

Table 2 outlines the items that factored together to form this belief dimension. Some items, such as "Ultimately the only thing that really counts is your final grade" may be measuring a student's goal in the course more than his/her beliefs about learning science. These seem to be overlapping dimensions that are not distinguishable based on factor analysis of student responses to Likert style items. While all the items had factor loadings above our cutoff of 0.3, these items which grouped into one factor category had previously been hypothesized to belong to two separate categories. The Cronbach alpha reliability coefficient for the ten beliefs about learning science items is 0.71. These items were not considered to create a reliable measure of student beliefs about learning science due to issues focusing on dimension overlap.

The final items were administered using a four-item Likert scale for response choices (strongly disagree, somewhat disagree, somewhat agree, strongly agree). While this measure could be used, conducting an interview analysis can possibly result in a better understanding of the variation in student beliefs about learning science. Descriptive statistics for item responses collecting repeated measures of this belief from survey 2 and 3, later in the semesters, are in Appendix A.

**Table 2: Summary and description of items averaged to measure student beliefs about learning science (BLS).**
Mean, standard deviation (SD), and factor loadings computed from responses to student beliefs about learning science (BLS) items. Responses collected during Fall 2009 survey administered at the beginning of the semester. (N=428)

| **Item** | **BLS Mean (SD)** | **Factor Loadings BLS** |
|---|---|---|
| I am more interested in learning chemistry than in the grade I earn | 2.62 (0.71) | 0.51 |
| There is more than one correct way to think about concepts in chemistry | 3.19 (0.65) | 0.40 |
| Chemistry does not always have one right answer to every problem | 3.05 (0.71) | 0.42 |
| When learning chemistry, I focus more on understanding the underlying theory than memorizing facts | 3.03 (0.67) | 0.44 |
| Science is not just facts to memorize independently, they relate to each other | 3.58 (0.56) | 0.50 |
| Ultimately the only thing that really counts is your final grade* | 2.71 (0.80) | 0.48 |
| I am only taking chemistry because it is required* | 2.60 (0.89) | 0.38 |
| Chemistry concepts are not that relevant to the real world* | 3.52 (0.64) | 0.44 |
| I just need to do enough work to pass this class* | 3.34 (0.71) | 0.33 |
| Science is just a lot of facts that you need to memorize* | 3.18 (0.77) | 0.47 |
| | | |
| **Composite BLS Variable** | 3.08 (0.38) | |

* Items were reverse coded so response indicates student disagreement with item

*Beliefs about their Academic Abilities*
The development of items to measure student beliefs about their academic abilities was based on self-concept items outlined by Bong and Skaalvik (2003). Focusing on measurement of students' self-concept in chemistry, items were tailored to prompt students to evaluate their past accomplishments or performance in chemistry. Items also prompted students to identify what they expected from their course performance. Response choices for these items were based on a four item Likert scale (strongly disagree, somewhat disagree, somewhat agree, strongly agree). Items to measure student beliefs about their academic ability did not require significant modifications throughout pilot testing and survey revisions.

From Table 3 it is evident that all items used to measure beliefs in their academic ability had a high response correlation since factor loadings for each item were above 0.45. The Cronbach alpha reliability coefficients, for the seven beliefs about their academic abilities items used in the Fall 2009 and eleven items used in the Fall 2010 survey versions, were 0.83 and 0.90 respectively. A look at the factor loadings and Cronbach alpha measures would show that these items create a reliable measure of the academic ability belief.

Table 3 below describes the items used during the Fall 2009 and Fall 2010 survey versions. Items used in Fall 2010 were revised based on those used in Fall 2009. Items that do not include descriptive statistics or factor loadings for a given survey version were not administered as part of that version. This allows for comparison of items used as well as additions or deletions made between the two survey versions. The primary difference was that the Fall 2010 survey included additional items to measure the ability dimension while only eliminating one item, "I can get an A in this class". This item was considered redundant with the later item "I expect to get an A in this class", and was replaced with the reverse wording in the item "I do not think I am capable of getting an A in this course". Surveys administered at the midpoint and end of semester included these items for repeated measure of the Ability belief. Descriptive statistics of these items from surveys administered later in the semester are given in Appendix A.

**Table 3: Summary and description of items averaged to measure student beliefs about their academic ability (Ability).**

Mean, standard deviation (SD), and factor loadings computed from responses to student beliefs in their academic ability (Ability) items. Responses collected from Fall 2009 and Fall 2010 surveys administered at the beginning of the semester. ($N_{2009}$=428; $N_{2010}$=597)

| **Item** | **Fall 2009** | | **Fall 2010** | |
|---|---|---|---|---|
| | **Ability Mean (SD)** | **Factor Loadings Ability** | **Ability Mean (SD)** | **Factor Loadings Ability** |
| I can get an A in this class | 3.29 (0.69) | 0.52 | | |
| I do well in math and science courses | 3.35 (0.64) | 0.46 | 3.32 (0.60) | 0.50 |
| I expect to get an A in this class | 2.96 (0.77) | 0.52 | 2.91 (0.82) | 0.50 |
| I already have a good understanding of chemistry from previous courses I have taken | 2.44 (0.94) | 0.66 | 2.29 (0.89) | 0.67 |
| Chemistry material does not come naturally to me * | 2.36 (0.83) | 0.76 | | |
| Understanding chemistry does not come naturally to me* | | | 2.37 (0.83) | 0.78 |
| I have to work much harder than my peers to do well* | 2.38 (0.87) | 0.68 | | |
| I have to work much harder than other students to do well* | | | 2.34 (0.84) | 0.62 |
| I am not very good at Chemistry* | 2.53 (0.84) | 0.80 | 2.50 (0.86) | 0.83 |
| I worry that I am not prepared for this class* | | | 2.01 (0.86) | 0.71 |
| I do poorly on Chemistry tests* | | | 2.73 (0.75) | 0.72 |
| I do not think I am capable of getting an A in this course* | | | 3.06 (0.82) | 0.65 |
| Chemistry is one of my best subjects | | | 2.06 (0.88) | 0.76 |
| I rarely need help to solve Chemistry problems | | | 2.02 (0.75) | 0.69 |
| **Composite Ability Variable** | 2.76 (0.56) | | 2.49 (0.58) | |

* Items were reverse coded so response indicates student disagreement with item

*Perceptions of the Classroom Environment*
It was difficult to create effective Likert style items to capture student perceptions of the classroom environment since we did not want to administer items which singled out different types of students. This was due to concerns that items of this nature might inadvertently invoke a stereotype threat situation (Steele & Aronson, 1995). After the initial survey version, testing Likert style items, failed to group these items based on factor analysis of student responses, the researcher decided to take a more student-generated approach. Students were asked during focus groups to list their top three concerns which they felt were affecting their current course performance. The students wrote down their responses, discussed their concerns, and explored similarities in types of concerns. From reviewing the lists created by students, and the concerns voiced during these focus group discussions, a list of the 14 most often expressed concerns was generated. This list was then administered as part of the Fall 2009 and Fall 2010 survey, as a drop down menu of choices to select from, allowing students to indicate what they perceived as the top three concerns hindering their course performance. The complete list of choices included topics ranging from financial concerns, family situations, to class environment. If a student selected as the top concern one of the three choices focusing on concerns related to the course environment, he/she was considered to perceive the classroom environment negatively. To create a dichotomous dummy variable to capture this, students who expressed concerns about the course over other available choices were coded as 1 and those who did not select one of these three choices as their highest concern were coded as 0. The complete list of choices is outlined in Figure 2 with those expressing a negative perception of the classroom environment indicated with asterisks.

**Figure 1: Screen shot of Fall 2010 survey showing item used to collect students selection of top 3 concerns.**

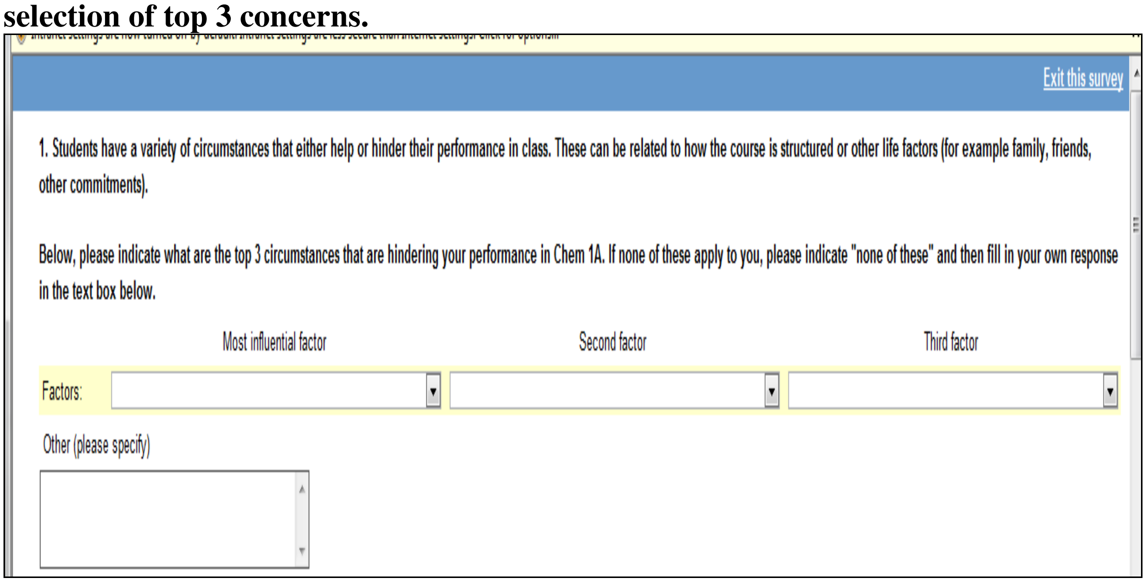


**Figure 2: Complete list of choices given for students to select from in drop-down menu.**

| |
|---|
| I often worry about financial circumstances |
| I have a lot of social or extra curricular commitments |
| I don't have a good place to study because of my living situation |
| Not enough time since my other classes are so demanding |
| I feel overwhelmed by the courses at Berkeley* |
| I have a lot of family obligations |
| I worry that I do not fit in very well at Berkeley |
| I am under a lot of pressure to do well |
| I am not very good at science |
| The atmosphere at Berkeley is intimidating* |
| I was not very well prepared by my high school |
| I don't have anyone to ask for help |
| My parents are not very supportive of me being at Berkeley |
| The other students in the course are very competitive* |
| None of these |

A second set of Likert style items was part of the Spring 2010 and Fall 2010 survey versions. These items were included in the second and third surveys administered during each of these semesters. They were not in the initial survey, which collected responses during the first few weeks of instruction, because it was hypothesized that students would not have had enough time to make a complete assessment of the course at this early time point.

Items developed and previously tested within the *What is Happening in This Classroom* (WIHIC) survey (Ali et al., 2008) were reviewed. The items developed for the survey in this research were based on a subset of the WIHIC items which had been found successful in measuring the equity, involvement, and support dimensions from the original WIHIC survey. The original WIHIC survey was designed and tested within a smaller class setting. Because of this, the wording of items reflected the professor as being the source of these actions or characteristics of the course. The analysis of the Spring 2010 responses showed that these items were found not to group well when administered with our larger class as indicated by the factor analysis. Based on these findings, the items were modified to represent student perceptions of the introductory chemistry "staff" since these various actions or references may be thought of in terms of the professor, graduate student assistant, or other support staff that students may interact with. It was not considered important for items to reference a specific person, but rather the staff acting as a team to address the actions outlined in these items.

Response choices for these items were based on a five-item Likert scale (almost never, seldom, sometimes, often, almost always). All items had a factor loading of 0.5 or above into the Equity dimension, as seen in Table 4. The Cronbach alpha reliability coefficient for the eight items used to measure student perceptions of the classroom environment in terms of equity was 0.90. Based on the high factor loadings and Cronbach's alpha, these items were considered to create a reliable measure of student perceptions of the classroom environment with respect to equity. Since only four out of the eight items from the involvement scale factored together, the measure of student perceptions of involvement within the course was not considered to be reliable and therefore was not used in further analysis. Table 4 below describes the items used during the Fall 2010 survey version to measure students equity perception of the classroom environment. A complete list of items administered on this Likert scale, including those aimed at measuring the involvement dimension, and their descriptive statistics, are included in Appendix A.

**Table 4: Summary and description of items averaged to measure student perceptions of the classroom environment equity scale (Equity).**
Mean, standard deviation (SD), and factor loadings computed from responses to student perception of the classroom environment equity scale (Equity) items. Responses collected from Fall 2010 survey administered mid-semester. ($N_{2009}$=428; $N_{2010}$=597)

| **Item** | **Equity Mean (SD)** | **Factor Loadings Equity** |
|---|---|---|
| The staff gives as much attention to my questions as to other students' questions | 3.76 (1.04 ) | 0.53 |
| I get the same amount of help from the staff as do other students' | 3.51 (1.05) | 0.53 |
| I have the same amount of say in this class as other students | 3.60 (1.08) | 0.58 |
| I am treated the same as other students in this class | 4.16 (0.89) | 0.89 |
| I receive the same encouragement from the staff as other students do | 3.80 (1.02) | 0.75 |
| I get the same opportunity to contribute to class discussions as other students | 3.92 (1.00) | 0.83 |
| My work receives as much praise as other students work | 3.41 (1.04) | 0.51 |
| I get the same opportunity to answer questions as other students | 3.92 (0.95) | 0.84 |
| | | |
| **Composite Equity Variable** | 3.76 (0.77) | |

*Perceptions of External Support*
Items created to measure student perceptions of external support focused on student perceptions of, or feeling that, a support system was present for them. Unlike previous studies using more open-ended questions (Robinson et al., 2007; Jacklin & Le Riche, 2009), this research developed Likert style items that focused on capturing student perceptions of support from different sources. Likert style items were initially created to reflect student sentiments reported through consultations with course instructors and other faculty. Knowing that previous research had found students to report their main sources of support to be from family and peers (Robinson et al. 2007; Jacklin & Le Riche, 2009) items were designed to specify family or friends. This was done to clarify

the source of support within many of the items. Additionally, items were worded to specify the chemistry course, science courses, or the university. Items capturing student perceptions of external support were modified throughout the various survey versions based on factoring results and further consultation with course instructors and faculty.

Response choices for these items were according to a four-item Likert scale (strongly disagree, somewhat disagree, somewhat agree, strongly agree). Table 5 describes the items used during the Fall 2009 and Fall 2010 survey versions. Items that do not have descriptive statistics or factor loadings included for the Fall 2009 version were new items used only in the Fall 2010 version. It is evident in Table 5, by comparison between items used during Fall 2009 and Fall 2010, that the main difference is that Fall 2010 items evolved to include more specific reference for the source of support (family/friends/parents). Four of these additional items in Fall 2010 focused on family-based support while the other two items specified peer-based support. The addition of these items is believed to have caused the split into two separate support dimensions. This split is attributed to providing sufficient items specifying these separate sources of support. One factor grouping contains items that focused more on family-based support, and the second factor grouping consists of items that specified more school-based or general support. This resulted in the creation of two support measures within the Fall 2010 version, one being the perception of family-based support and the other being a perception of more general external support.

All items had a factor loading of 0.3 or above into their support dimension, as seen in Table 5. The Cronbach alpha reliability coefficient for the seven perception of external support items used in the Fall 2009 is 0.67. In the Fall 2010 survey version, the Cronbach alpha reliability coefficients for the eight items used to measure the perception of family-based support and five items used to measure the perception of school-based support are 0.71 and 0.69 respectively. While these Cronbach alpha coefficients are not well above the desired 0.70 they were considered adequate to establish reliability of this measure. Surveys administered later in the semester used these same items to collect repeated measures of support. Descriptive statistics of these items from later surveys are given in Appendix A.

**Table 5: Summary and description of items averaged to measure student perceptions of external support (Support, Support Family, Support School).**
Mean, standard deviation (SD), and factor loadings computed from responses to student perceptions of external support (Support, Support Family, Support School) items. Responses collected from Fall 2009 and Fall 2010 surveys administered at the beginning of the semester. ($N_{2009}$=428; $N_{2010}$=597)

| | **Fall 2009** | | **Fall 2010** | | |
|---|---|---|---|---|---|
| **Item** | **Support Mean (SD)** | **Factor Loadings Support** | **Support Mean (SD)** | **Factor Loadings Support Family** | **Factor Loadings Support School** |
| It is difficult to find other students to study with in chemistry* | | | 2.98 (0.78) | | 0.60 |
| I have friends in this class | | | 3.21 (0.78) | | 0.46 |
| I know people I can call for help when I have questions about chemistry | | | 3.02 (0.77) | | 0.61 |
| I have people I can call for help when I have questions about chemistry | 2.90 (0.79) | 0.35 | | | |
| I do not have a great network of support* | 2.98 (0.80) | 0.52 | 3.05 (0.80) | | 0.48 |
| I do not have anyone to call when I am frustrated or overwhelmed with school* | 3.39 (0.80) | 0.73 | 3.39 (0.77) | | 0.35 |
| My friends believe in me | 3.35 (0.61) | 0.40 | 3.45 (0.58) | 0.31 | |
| Someone in my family is always there for me | 3.39 (0.82) | 0.61 | 3.46 (0.73) | 0.54 | |
| My family understands the struggles of studying science in college | 2.81 (0.90) | 0.31 | 2.89 (0.82) | 0.45 | |
| My parents are proud that I am at UC Berkeley | 3.63 (0.62) | 0.30 | 3.66 (0.57) | 0.54 | |
| My parents care more about what I learn than the grades I earn | | | 2.60 (0.88) | 0.33 | |
| My family encourages me and provides motivation when I doubt my abilities in science | | | 3.14 (0.73) | 0.57 | |
| My parents support me in making my own choices about my college education | | | 3.34 (0.70) | 0.56 | |
| My parents would prefer that I stay at home and look for a job* | | | 3.81 (0.47) | 0.35 | |
| | | | | | |
| **Composite Support Variable** | 3.21 (0.45) | | | | |
| **Composite Support Variable**<br>Family<br>School | | | <br>3.29 (0.40)<br>1.88 (0.52) | | |

* Items were reverse coded so response indicates student disagreement with item

*Use of Resources*

The initial plan was to collect measures of student behavior towards use of resources using survey items. The first attempts at measurement of student use of resources were targeted at collecting information on what resources a student was utilizing given their available choices. Items asked students to indicate, from a list of options, which of the course resources they used when studying. Attempting to gain more insight, students were also asked to indicate for each resource how often they engaged in the use of each resource (never, 1-2 times so far this semester, once a week, 2-3 times per week, every day). These measures captured what types of resources the students were taking advantage of and how often they engaged with them.

During Fall 2009, while interviewing students, it was realized that while two students may report to have used the same type of resource, they may have demonstrated very different behaviors when engaged with this resource. As a result of this realization, measures were collected of how often students were asking questions, answering questions, listening to others, and explaining their thinking when working with others. An item was also added asking students to indicate which best described their approach when using past years exams to study from, given the description of several different approaches. These items were further revised to have more concrete response choices for the Fall 2010 survey. Response choices of how much time they spent asking questions and the like were changed from "most of the time, some of the time, rarely, almost never" to more quantitative evaluations of "over 75% of the time, between 50-75% of the time, between 25-50% of the time, less than 25% of the time".

After further analysis of the interviews collected during Fall 2009 (see chapter 6 for full details of interview analysis), the difficulty in capturing student behavior towards use of resources from survey items was realized. Two students may report the same responses on items about behavior, such as studying with peers primarily asking questions as their main resource and behavior. Depending on the types of questions asked and application of the answers, these two students' behavior may differ. One student may work with peers, may ask a lot of questions and may rely on the help of others to find the answers. The second student, while still working with peers and asking questions, may then take an additional step of evaluating the answers given. This second student may then engage in dialogue clarifying the reasoning behind the information told and translate this into his/her own words or understanding of the ideas. While these two students are engaging very differently with the indicated resource they may both describe their engagement as "asking questions" on the survey.

The depth of how students are using the resources they report was not easily captured through survey responses. While some performance differences were found when comparing the students grouped according to the type of resources they used or their behavior when working in groups, the researchers were not convinced that the reasons behind these findings were so straightforward. Given these considerations, the items in the survey, on the final measures of student behavior for use of resources, were not included in the analysis of the model. In future versions of the survey, items measuring student behavior towards use of resources would not be included. Alternatively, student's interview responses were used to measure this behavior. For complete details of use of resource behavior measurement and its effects on student performance see Chapter 6.

**Discussion**

Through the development of survey items, this chapter addressed issues of measurement reliability, and determined which student beliefs and perceptions could be captured with survey data. The focus was constrained to beliefs and perceptions that met the following three criteria: (1) shaped by students prior experiences; (2) found previously to effect student performance; and (3) instructors had the capacity to intervene. While student beliefs about learning science had proven difficult to measure, the degree to which items across each dimension factored into predicted categories established the effectiveness of items generated based on our design hypothesis. Using the following three criteria proved to generate reliable measurement items: (1) ensure clear and concise wording to minimize multiple interpretations; (2) use language that is consistent with students use and knowledge; and (3) relate each item specifically to the chemistry course to lessen the inclusion of related beliefs or opinions towards science as a more general subject. Given these findings, the final survey versions from Fall 2009 and Fall 2010 include items which measured student: (1) beliefs about their academic abilities; (2) perceptions of external support structures; (3) perceptions of the classroom environment (4) beliefs about learning science (Fall 2009 only); and (5) demographic information.

Survey items generated for this research were based on previous literature findings as well as consideration of the three criteria outlined in the design hypothesis. Student beliefs about learning science have been found difficult to measure through survey items (Lederman et. al, 2002; Songer & Linn, 1991) but an attempt was made so as not to restrict sample size only to those who were interviewed. Although items to create a robust measure were not found, the issues identified with dimension overlap could help in the development of future items for this belief. Items to measure student beliefs in their academic abilities were based on those outlined by Bong & Skaalvik (2003) to measure self concept, or a student's general perceptions of the self in the domain of chemistry. This survey was intended primarily for students who were entering their first college science course and who were not yet familiar with the demands at the college level. Self-concept was a more appropriate measure of academic ability since items tended to direct the attention of respondents toward their past accomplishments. Items measuring student beliefs in their academic ability needed little revision, having factor loadings of above 0.45 for all items. Student perceptions of the classroom environment took a more generative approach. Focus group findings lead to the creation of a list of student concerns from which respondents selected their own top concern. An additional measure of student perceptions of equity within the classroom was designed based on items from the *What is Happening in This Classroom* (WIHIC) survey (Ali et al., 2008). The modification of items to consider the perception of the staff acting as a team for this large course proved effective. All items had a factor loading of 0.5 or above into this dimension for perception of classroom environment with respect to equity. Creating two measures of the perception of the classroom environment from such different approaches adds value for the ability to compare their effects. Similar to reasons behind the use of

Likert style items to capture beliefs about learning science, Likert style items to measure student perceptions of external support were created to allow for response collection from a large population. Open-ended items have been reported in current literature capturing this perception (Jacklin & Le Riche, 2009; Robinson et al., 2007), leaving items for this survey to be generated based on findings from these more open-ended items. Past studies indicating family and peers as the main source of support cited by students (Robinson et al., 2007) influenced our decision to identify family, peers, or other close individuals as possible sources. The factoring into two groups during Fall 2010, one indicating family based support, the other more general peer support, resulted in factor loadings above the 0.3 criterion. The factor loadings in Fall 2009 and 2010 were all above the 0.3 criterion, and agreement with items grouping together into predicted dimensions indicate the strength of association of the items created for use in this survey.

This collection of surveys could be used in the future to measure student beliefs and perceptions over the semester. These measures could identify students who may be at risk of performing poorly on exams based on past trends. Curricular interventions could be given to those identified. Using the strengths found in the items from each survey, future versions of the survey would include Likert items from the Fall 2009 version to measure (1) beliefs about their academic abilities; (2) perceptions of external support, along with Likert items from Fall 2010; and (3) perceptions of the classroom environment. Additionally, a future survey instrument would include measures of student perceptions of the classroom environment using the drop down menus administered in both Fall 2009 and Fall 2010 versions as well as demographic information collected in the same fashion as the surveys in Fall 2009 and Fall 2010.

## Chapter 5: Relationship Between Student Beliefs, Perceptions and Course Performance

### Introduction

This chapter uses measures of student beliefs and perceptions to determine their influence on student exam performance. This is done through an analysis of measures collected with the Chemistry Beliefs and Perceptions Survey (see chapter 4 for complete details of the Chemistry Beliefs and Perceptions Survey). The analysis evaluates for possible influences on student performance in undergraduate introductory chemistry. The four beliefs and perceptions measures collected and used in the analysis are:

1) beliefs about learning science;
2) beliefs about their academic abilities;
3) perceptions of the classroom environment; and
4) perceptions of external support.

This analysis answers the first research question, "How do student beliefs about learning science, beliefs about their academic abilities, perceptions of the classroom environment, and perceptions of external support affect course performance?" The findings from this analysis are useful in determining the direct effects of these beliefs and perceptions on student exam performance, as well as possible interactions between individual beliefs and perceptions.

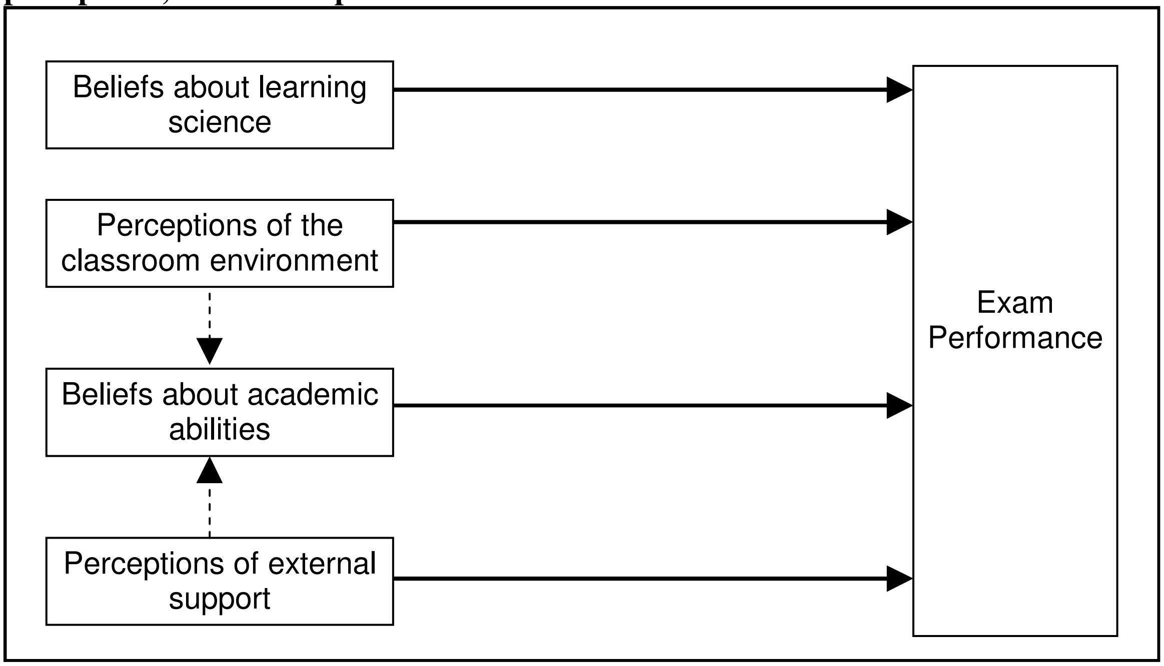
### Rationale

Before testing for the effects of student beliefs and perceptions on course performance, literature for each of these was reviewed. Literature findings on each of the beliefs and perceptions were used to inform the final logic model used for analysis. This section presents the logic model generated for use in the analysis based on the current literature. Then the literature used to develop the logic model is presented to explain the influence each belief and perception may have on each other and on course performance.

*Logic Model*

The final logic model used for analysis is shown in Figure 3. The solid lines represent the effects of student beliefs and perceptions on course exam scores that will be evaluated. The dashed lines represent possible interactions between beliefs and perceptions that will be evaluated as well.

**Figure 3: Evaluation logic model used to determine relationship between beliefs, perceptions, and course performance**




*Beliefs About Learning Science*

How do student beliefs about learning science impact course performance? While some students may view science as memorization of a set of facts (static), others believe that learning science requires understanding how scientific concepts are interconnected and how linking these different concepts can explain the observed phenomena (dynamic). Songer and Linn (1991) characterized student views of science based on survey responses. Students were categorized into three groups: static, dynamic, and mixed between static and dynamic. Songer and Linn (1991) found that students in the static belief group were somewhat less successful than students in the dynamic belief group in forming links between multiple ideas. This was found from student test results after being given instruction in thermodynamics. While they did not find a large difference in student overall performance, their results demonstrated the possibility that dynamic beliefs may increase student understanding by increasing emphasis on conceptual understanding or integration of ideas by the student. Using a variety of methods to explore the relationship between beliefs about learning science and learning of science content, many studies found evidence to support the findings by Songer and Linn (1991) that a more dynamic view of science leads to a deeper understanding of the content (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Rosenberg, Hammer, & Phelan, 2006; Songer & Linn, 1991; Stathopoulous & Vosniadou, 2007).

*Beliefs About Their Academic Abilities*

What is the influence of student beliefs about their academic abilities in chemistry on course performance? House (1995) considered several predictors of college chemistry performance such as ACT score, number of math courses taken, and student self rating of his/her grade expectations in college eliciting student self-concept. When responses to these items were correlated with their introductory chemistry grade, House (1995) found that student self-concept was a significant predictor of college chemistry course grade. Compared with ACT scores and mathematics courses, initial attitudes of performance, or self-concept, were found to be better predictors of college chemistry performance (House, 1995). Nieswandt (2007) found similar effects of self-concept when studying high school students learning chemistry. Nieswandt (2007) measured student situational interest, attitudes towards chemistry, and chemistry-specific self-concept at two time points: the middle and end of semester. They found evidence that earlier self-concept acted as a mediator along with situational interest in influencing later self-concept, and that this later self-concept had a positive effect on conceptual understanding in chemistry (Nieswandt, 2007). These findings demonstrating the positive impact of self-concept on course performance or conceptual understanding led this study to hypothesize that belief about academic abilities would have a positive effect on course performance.

*Perceptions of the Classroom Environment*

Ali, Rohindra, and Coll (2008) explored the differences in perceptions between cultural groups in a class and the impact these perceptions had on performance. This was done in a multi-cultural university-level environment through analysis of student responses to the *actual* and *preferred* versions of a learning environment instrument, the *What is Happening in This Classroom* (WIHIC) survey. The WIHIC survey findings suggest all students would prefer a more interactive and equitable classroom, yet some minority students perceived the actual environment differently on the scales of "involvement" and "equity" (Ali et al., 2008). These findings on environmental perception highlight the importance of evaluating how students perceive the classroom and the perception differences between groups of students. Literature contained in the area of stereotype threat was also considered to evaluate the effect of perception of the classroom environment on exam performance. The Stereotype Threat Model (Steele & Aronson, 1995) posits that, when individuals from a group perform a difficult task in an area in which the group is characterized as weak, they feel at risk of confirming the stereotype, and psychological pressure will lead them to under perform. There is a possibility that creating a more supportive learning community will create alternate, more positive identities, with which students can associate (McGlone & Aronson, 2006).

Along with these findings suggesting direct effects on exam performance is a possible interaction between student perception of the classroom environment and belief about his/her academic abilities. Britner and Pajares (2006) confirmed four sources of student beliefs about his/her academic ability in terms of self-efficacy. Two of these four sources, vicarious experiences and physiological states, are related to perception of the classroom environment or factors influencing stereotype threat. Vicarious experiences refer to students identifying with someone else and evaluating that they will have the same ability or outcome as the person they are observing. If students identify with others that are doing well in the course they will have a positive vicarious experience resulting in increased belief in their abilities. Physiological states refer to a student's possible feelings of nervousness or discomfort with science. If students feel uncomfortable within a classroom environment this may result in a decrease in their belief in their abilities (Britner & Pajares, 2006). Based on these literature findings, the model used for this analysis includes evaluation of both direct and interaction effects from student perceptions of the classroom environment.

*Perceptions of External Support*
How does one's perception of peer and family support or expectations influence academic achievement at the university level? Roman, Cuestas, and Fenollar (2008) examined the relationship between self-esteem, others' expectations, family support, and learning approaches, on achievement at the university level. Family support was defined as an individual's perception that he or she is cared for, esteemed and valued by his or her family (Roman et al., 2008). Citing previous research demonstrating the importance of parental expectations and college plans for children over other outside support, Roman et al. (2008) found that family support increased academic achievement at the university level. The effects of perceived family support on a student's academic achievement were meditated by the learning approach. Increased academic achievement was attributed to an increase in deep processing, effort, and self-esteem due to the influence of perceived family support.

Similar to findings connecting student perceptions of the classroom environment with beliefs about their academic abilities, there may be a link between the perceptions of external support and beliefs about academic abilities. One of the four sources influencing the development of student beliefs of academic ability is social persuasions (Britner & Pajares, 2006). Social persuasions refer to the belief that others (teachers, peers, family) believe in their ability to perform well. Social persuasions can be equated to student perceptions of an external support. Analysis of measures from the Student Beliefs and Perceptions survey further expands the model suggested by Roman et al. (2008). The analysis considers findings from Britner and Pajares (2006) to test student beliefs about their academic abilities as a possible mediator between perceived external support and course performance.

**Methods**
Data was collected through responses to the Student Beliefs and Perceptions Survey (SBPS) administered online via surveymonkey.com (an online survey system) in an introductory chemistry course. The SBPS is a collection of three surveys developed for administration at the beginning, midpoint, and end of the semester. The surveys include items measuring student: (1) beliefs about learning science; (2) beliefs about their academic abilities; (3) perceptions of the classroom environment; (4) perceptions of external support; and (5) demographic information. Information on the development and testing of the survey instrument is included in Chapter 4. Students were invited during the second week of instruction to participate through an email. The email was sent from the course webpage containing a link to the first survey. At the midpoint of the semester and during the last week of class, students were asked to complete follow-up surveys collecting repeated measures of student beliefs and perceptions along with an additional measure of their perceptions of the classroom environment. Survey responses were collected from all students in the course who consented to participate.

Using student responses collected during Fall 2009 and Fall 2010, variables were created to capture student: (1) beliefs about learning science (Fall 2009 only); (2) beliefs about their academic abilities; (3) perceptions of the classroom environment; and (4) perceptions of external support. Variables were created based on factoring and reliability information obtained during the development of the survey instruments. Analysis of the Fall 2010 survey responses were used to confirm repeatability of findings from Fall 2009. Details on the development of these measures and reasons behind the items used to create these variables are outlined in Chapter 4. Dummy variables were created for selected demographic information. Students were identified through student ID numbers to link with course exam grades. Student exam grades were combined with their survey responses to create the final data sets used for analysis.

**Table 6: Summary of student measures collected during the semester.** Occasion 1 corresponds to the first exam in the course and measures collected from first survey administration. Occasion 2 corresponds to the second exam in the course and second survey administration. Occasions 3 and 4 correspond to the fourth and final exams respectively, and each correlate to measures from the final survey administration.

| | **Beginning (Occasion 1)** | | **Mid-Semester (Occasion 2)** | | **Ending (Occasion 3)** | | **Ending (Occasion 4)** | |
|---|---|---|---|---|---|---|---|---|
| | **Fall 2009** | **Fall 2010** | **Fall 2009** | **Fall 2010** | **Fall 2009** | **Fall 2010** | **Fall 2009** | **Fall 2010** |
| **Exam score** | ● | ● | ● | ● | ● | ● | ● | ● |
| **Beliefs about Learning Science** | ● | | ● | | ● | | ● | |
| **Beliefs about Academic Ability** | ● | ● | ● | ● | ● | ● | ● | ● |
| **Perceptions of the Classroom Environment** | ● | ● | | ● | | ● | | ● |
| **Perception of External Support** | ● | ● | ● | ● | ● | ● | ● | ● |
| **Demographics** | ● | ● | | | | | | |

A hierarchical linear model was used to test for the effect of each of the beliefs and perceptions on course exam performance, over time. Further descriptions of the variables used, analysis models, and findings are provided below.

## Participants

Participants were students enrolled in the introductory chemistry course at a large public university. This course enrolls approximately 1300 students each Fall semester. This course is designed for non-chemistry majors who need to take chemistry as a pre-med or major requirement.

All students in the course were invited to participate in the study. Of the students who participated during Fall 2009 and Fall 2010, those who gave consent for use of their responses and responded to all three surveys administered during the semester were included in the final analysis. Some students responded to all three surveys yet they skipped some items. Students who did not respond to all items used for variable creation and analysis were excluded from the final sample. Table 7 outlines the demographic make-up of the final samples used for analysis collected during Fall 2009 and Fall 2010.

**Table 7: Demographic summary of response populations in Fall 2009/2010.** Number of students (N), and percentage of sample population (%), self reporting to be included in each demographic category for each sample population. Each of the demographic categories were represented by dummy variables for analysis. Data includes only students who responded to all 3 surveys. SES refers to students' socio-economic status. ($N_{2009}$=428; $N_{2010}$=597)

| Variable | Category | Fall 2009 | | Fall 2010 | |
|---|---|---|---|---|---|
| | | N | % | N | % |
| **Major** | Life Science* | 225 | 52.6 | 334 | 55.9 |
| | Engineering | 94 | 22.0 | 106 | 17.8 |
| | Physical Science/Mathematics | 10 | 2.3 | 20 | 3.3 |
| | Humanities | 15 | 3.5 | 29 | 4.9 |
| | Undeclared | 62 | 14.5 | 77 | 12.9 |
| | Other | 22 | 5.1 | 31 | 5.2 |
| | | | | | |
| **SES** | Wealthy | 11 | 2.6 | 15 | 2.5 |
| | Upper-middle or professional middle | 165 | 38.6 | 213 | 35.7 |
| | Middle-class* | 157 | 36.7 | 266 | 44.6 |
| | Working-class | 43 | 10.0 | 60 | 10.0 |
| | Low-income or poor | 52 | 12.1 | 43 | 7.2 |
| | | | | | |
| **Ethnicity** | Chinese/Chinese-American | 142 | 33.2 | 165 | 27.6 |
| | East Indian/Pakistani | 27 | 6.3 | 31 | 5.2 |
| | Korean/Korean-American | 47 | 11.0 | 43 | 7.2 |
| | South East Asian | 17 | 4.0 | 37 | 6.2 |
| | Other Asian | 25 | 5.8 | 31 | 5.2 |
| | Mexican/Mexican-American/African-American/Black | 10 | 2.3 | 23 | 3.9 |
| | White* | 98 | 22.9 | 144 | 24.1 |
| | Mixed | 47 | 11.0 | 82 | 13.7 |
| | Other | 15 | 3.5 | 41 | 6.9 |
| | | | | | |
| **Gender** | Female* | 264 | 61.7 | 356 | 59.6 |
| | Male | 164 | 38.3 | 241 | 40.4 |
| | | | | | |
| **Total** | | **428** | | **597** | |

*used as reference category in regression analysis

## Variables Created

Variables for analysis were created from survey responses collected in Fall 2009 and Fall 2010. Table 8 provides details on the type of variables created, the scale used, and when they were measured. Subscales labeled Ability, Support, Support_School (2010 only), Envp_Equity (2010 only) and BLS (2009 only) were created based on previous factor analysis results (see Chapter 4 for complete details). Information on these subscales, and other variables created are given in more detail below. Occasion collected refers to the time during the semester each of these measures was collected. Each occasion correlates with the week after an exam was administered. An additional exam (exam 3) was administered between occasions 2 and 3, but this was not included for analysis since no other measures were collected at this time. Survey responses were collected at occasion

1 (the week after exam 1), occasion 2 (the week after exam 2), and in the two week period between occasions 3 and 4 (between the fourth and final exam in the course). Considering the short time period between occasions 3 and 4, measures collected from survey responses during those two weeks were included to correlate with exam scores at each occasion.

**Table 8: Summary of variables used for analysis.** Includes their type, range, and occasion they were collected.

| Variable | Used As | Type | Scale | Occasion Collected 2009 | Occasion Collected 2010 |
|---|---|---|---|---|---|
| Exam1 | Response | Continuous | 0-100 | 1 | 1 |
| Exam2 | Response | Continuous | 0-100 | 2 | 2 |
| Exam4 | Response | Continuous | 0-100 | 3 | 3 |
| ExamFinal | Response | Continuous | 0-100 | 4 | 4 |
| Ability | Explanatory | Continuous | 1-4 | 1,2,3/4 | 1,2,3/4 |
| Support | Explanatory | Continuous | 1-4 | 1,2,3/4 | 1,2,3/4 |
| Support_School | Explanatory | Continuous | 1-4 | | 1,2,3/4 |
| EnvP | Explanatory | Dichotomous | 0/1 | 1 | 1 |
| Envp_Equity | Explanatory | Continuous | 1-5 | | 2, 3/4 |
| BLS | Explanatory | Continuous | 1-4 | 1,2,3/4 | |
| 5 dummies for major | Explanatory | Dichotomous | 0/1 | 1 | 1 |
| 4 dummies for SES | Explanatory | Dichotomous | 0/1 | 1 | 1 |
| 8 dummies for ethnicity | Explanatory | Dichotomous | 0/1 | 1 | 1 |
| Female | Explanatory | Dichotomous | 0/1 | 1 | 1 |
| Occasion | Explanatory | Categorical | 1/2/3/4 | 1 | 1 |
| Suppability | Explanatory | Continuous | 1-16 | 1,2,3/4 | 1,2,3/4 |
| Envpability | Explanatory | Continuous | 0-4 | 1 | 1 |

Exam scores were standardized by converting them into percentile scores for this study. This was done to account for the fact that each exam had questions relating to different chemistry content and the exams may have varied in difficulty over the semester.

**Exam** represents student exam scores, standardized (percentile scores)

- **Exam1** represents the students first exam score for the course, focusing on the "matter" unit in the course
- **Exam2** represents the students second exam score for the course, focusing on the "change" unit in the course
- **Exam4** represents the students fourth exam score for the course, focusing on the "quantum" unit in the course
- **ExamFinal** represents the students final exam score for the course, a cumulative final exam

**Ability** represents the variable created to capture student beliefs in their academic ability**.** The subscale labeled “Ability” was created by averaging student Likert scale responses to the items in Figure 4 (grouping determined from factor analysis results, see Chapter 4 for details). The responses were coded 1=strongly disagree, 2=somewhat disagree, 3=somewhat agree, 4=strongly agree. Reverse scale in Figure 4 indicates students responses were considered to be the reverse of the scale above when coding them. All Ability items have a factor loading of 0.46 or higher into their subscale (see Chapter 4). The Cronbach alpha reliability coefficients measured at occasion 1 for the seven items used to create the variable Ability in the Fall 2009 and eleven items used in the Fall 2010 survey versions are 0.83 and 0.90 respectively. Reliability was determined based on the factor loadings being above 0.30 and Cronbach alpha above 0.70.

**Figure 4: Likert response items averaged to create Ability variable**

| 2009 Ability Items | 2010 Ability Items |
|---|---|
| • I can get an A in this class<br>• I do well in math and science courses<br>• I expect to get an A in this class<br>• I already have a good understanding of chemistry from previous courses I have taken<br><br>• The reverse scale of "I am not very good at Chemistry"<br>• The reverse scale of "Chemistry material does not come naturally to me"<br>• The reverse scale of "I have to work much harder than my peers to do well" | • Chemistry is one of my best subjects<br>• I rarely need help to solve Chemistry problems<br>• I do well in math and science courses<br>• I expect to get an A in this class<br>• I already have a good understanding of chemistry from previous courses I have taken<br><br>• The reverse scale of "I am not very good at Chemistry"<br>• The reverse scale of "Understanding chemistry does not come naturally to me"<br>• The reverse scale of "I have to work much harder than other students to do well"<br>• The reverse scale of "I worry that I am not prepared for this class"<br>• The reverse scale of "I do poorly on Chemistry tests"<br>• The reverse scale of "I do not think I am capable of getting an A in this course" |

**Support** represents the variable created to capture student perceptions of external support (primarily family based in 2010). The subscale labeled “Support” was created by averaging student Likert scale responses to the items listed below in Figure 5 (for complete factor analysis results see Chapter 4). The responses were coded 1=strongly disagree, 2=somewhat disagree, 3=somewhat agree, 4=strongly agree. Reverse scale in Figure 5 indicates student responses were considered to be the reverse of the scale above when coding them. All Support items have a factor loading of 0.3 or higher into their subscale (see Chapter 4). The Cronbach alpha reliability coefficient for the seven items used to create the Support variable at occasion 1 in Fall 2009 is 0.67. For the Fall 2010 survey version administered at occasion 1 the Cronbach alpha reliability coefficient for the eight items used to create the Support variable is 0.71. Reliability was determined based on the factor loadings being above 0.30 and Cronbach alpha above or adequately close to 0.70.

**Figure 5: Likert response items averaged to create Support variable**

| Fall 2009 Support Items | Fall 2010 Support Items |
|---|---|
| • My friends believe in me<br>• Someone in my family is always there for me<br>• My family understands the struggles of studying science in college<br>• My parents are proud that I am at UC Berkeley<br>• I have people I can call for help when I have questions about chemistry<br><br>• The reverse scale of "I do not have a great network of support"<br>• The reverse scale of "I do not have anyone to call when I am frustrated or overwhelmed with school" | • My friends believe in me<br>• Someone in my family is always there for me<br>• My family understands the struggles of studying science in college<br>• My parents are proud that I am at UC Berkeley<br>• My parents care more about what I learn than the grades I earn<br>• My family encourages me and provides motivation when I doubt my abilities in science<br>• My parents support me in making my own choices about my college education<br><br>• The reverse scale of "My parents would prefer that I stay at home and look for a job" |

**Support_School** represents the variable created to capture student perceptions of external support that are primarily school/peer based (measured during Fall 2010 only). The subscale labeled "Support_School" was created by averaging five student Likert scale responses (for complete factor analysis results see Chapter 4). The responses were coded 1=strongly disagree, 2=somewhat disagree, 3=somewhat agree, 4=strongly agree. Reverse scale in Figure 6 indicates student responses were considered to be the reverse of the scale above when coding them. All Support_School items have a factor loading of 0.36 or higher (see Chapter 4). Cronbach alpha for the five items used to create the Support_School variable at occasion 1 in Fall 2010 is 0.69. Reliability was determined based on the factor loadings being above 0.30 and Cronbach alpha above or adequately close to 0.70.

**Figure 6: Likert response items averaged to create Support_School variable**

| Fall 2010 Support_School Items |
|---|
| • I have friends in this class<br>• I know people I can call for help when I have questions about chemistry<br><br>• The reverse scale of "It is difficult to find other students to study with in chemistry"<br>• The reverse scale of "I do not have a great network of support"<br>• The reverse scale of "I do not have anyone to call when I am frustrated or overwhelmed with school" |

**EnvP** represents the variable created to capture student perceptions of the classroom environment at the beginning of the course. EnvP was a dummy variable created to indicate if a student expressed concerns about the course environment at occasion 1.

Students were asked to select their top three concerns from a given set of choices ranging from financial concerns, family situations, to class environment. EnvP was coded as 1 if a student selected a concern about the course environment above all other choices. If a student did not select one of these choices, relating to course environment as their top concern, then EnvP was coded as 0. The choices coded for expressing concern are listed below:

- The atmosphere at Berkeley is intimidating;
- The other students in the course are very competitive; and
- I feel overwhelmed by the courses at Berkeley.

**Envp_Equity** represents the variable created to capture student perceptions of the classroom environment in terms of equity (measured during Fall 2010 only). The subscale labeled "Envp_Equity" was created by averaging eight student Likert scale responses (for complete factor analysis results see Chapter 4). The responses were coded 1=almost never, 2=seldom, 3=sometimes, 4=often, 5=almost always. All Envp_Equity items have a factor loading of 0.51 or higher (see Chapter 4). The Cronbach alpha reliability coefficient for the eight items used to create the Envp_Equity variable at occasion 2 during Fall 2010 is 0.90. Reliability was determined based on the Cronbach alpha being above 0.70.

**Figure 7: Likert response items averaged to create Envp_Equity variable**

| **2010 Envp_Equity Items** |
| --- |
| • The staff gives as much attention to my questions as to other students' questions<br>• I get the same amount of help from the staff as do other students<br>• I have the same amount of say in this class as other students<br>• I am treated the same as other students in this class<br>• I receive the same encouragement from the staff as other students do<br>• I get the same opportunity to contribute to class discussions as other students<br>• My work receives as much praise as other students work<br>• I get the same opportunity to answer questions as other students |

**BLS** represents the variable created to capture student beliefs about learning science (measured during Fall 2009 only). The subscale labeled "BLS" was created by averaging ten student Likert scale responses (for complete factor analysis results see Chapter 4). The responses were coded 1=strongly disagree, 2=somewhat disagree, 3=somewhat agree, 4=strongly agree. Reverse scale in Figure 8 indicates student responses were considered to be the reverse of the scale above when coding them. All BLS items have a factor loading of 0.33 or higher (see Chapter 4). The Cronbach alpha reliability coefficient for the ten items used to create the BLS variable measured at occasion 1 in Fall 2009 is 0.71. Reliability was determined based on the factor loadings being above 0.30 and Cronbach alpha above 0.70.

**Figure 8: Likert response items averaged to create BLS variable**

| **2009 BLS Items** |
|---|
| • I am more interested in learning chemistry than in the grade I earn<br>• There is more than one correct way to think about concepts in chemistry<br>• Chemistry does not always have one right answer to every problem<br>• When learning chemistry, I focus more on understanding the underlying theory than memorizing facts<br>• Science is not just facts to memorize independently, they relate to each other<br><br>• The reverse scale of "Ultimately the only thing that really counts is your final grade"<br>• The reverse scale of "I am only taking chemistry because it is required"<br>• The reverse scale of "Chemistry concepts are not that relevant to the real world"<br>• The reverse scale of "I just need to do enough work to pass this class"<br>• The reverse scale of "Science is just a lot of facts that you need to memorize" |

**Suppability** represents the variable created to capture the interaction of Support with Ability (Support x Ability)

**Envpability** represents the variable created to capture the interaction of EnvP with Ability at occasion 1 (EnvP x Ability)

Student major, socio-economic status (SES), ethnicity, and gender were collected by student self-report from the available options given. For major, SES, and ethnicity, the dummy variables represent the possible response options available to the students. Major "Physci_Math" was created as a combination of students who selected physical science or mathematics. Ethnicity "Mexican_Black" was created as a combination of students who selected Mexican/Mexican-American or African-American/Black. Ethnicity Otherasian was modified to include students who selected Japanese/Japanese-American, and Seasian was modified to include students who selected Filipino. Ethnicity Other was created as a combination of students who selected Other, International Student, Middle Eastern, or Spanish/Spanish-American. Ethnicity Mixed was created to include all students who selected more than one ethnic category. Below describes the dummy variables created to capture student demographic self-reports.

- Dummy variables created to represent major are: engineering (Engineering), physical science/mathematics (Physci_Math), humanities (Humanities), undeclared (Undeclared), other (Othermajor);with life science (Lifesci) as reference.
- Dummy variables created to represent SES are: Wealthy (SES_Wealthy), Upper-middle or professional middle (SES_Uppmiddle), Working-class (SES_Working), Low-income or poor (SES_Low);with Middle-class (SES_Middle) as reference
- Dummy variables created to represent ethnicity are: Chinese/Chinese-American (Chinesechineseamerican), East Indian/Pakistani (Eastindianpakistani), Korean/Korean-American (Koreankoreanamerican), South East Asian (Southeastasian), Other Asian (Otherasian), Mexican/African-American/Black (Mexican_Black), Students who indicated more than one ethnicity (Mixed), Other ethnicity (Otherethnicity); with White (White) as reference

- Dummy variable created to represent gender (Female): female=1, male or transgender=0

**Occasion** represents the time identifier
- Dummy variables created for Occasion are: Occasion1, Occasion2, Occasion3 Occasion4

**Analytic Plan**
The data collected were panel data with exam scores and survey measures collected at each occasion. An additional exam (exam 3) was administered between occasions 2 and 3, but this was not included for analysis since no other measures were collected at this time. Survey measures collected during the two week period between occasions 3 and 4 were included in the model, at each of these occasions, as separate measures for each occasion. Since occasions 3 and 4 were so close together it was considered a safe assumption that student beliefs and perceptions would not vary between occasions, and so could be used to explain each exam score separately. For the dataset, student exam scores and measures of student beliefs and perceptions, were reshaped to correlate with their respective occasions.

A hierarchical linear model was used to analyze the longitudinal data. Here the level-1 units are occasions and the level-2 units are students. The models include a random intercept for students to accommodate within-student correlations of test scores over time. Each of the models evaluate the direct effects student beliefs (BLS, Ability) and perceptions (Support, EnvP) have on course exam score, over the semester. Demographic variables are used in this model for control.

The model listed below for Fall 2009 represents model 2 in the results (see Table 13). Model 2 includes measures for each student beliefs and perceptions. Model 1 does not include a measure for student beliefs about learning science (BLS). Models 3 and 4 include the addition of interaction terms (Envp_Ability, SuppAbility).

Fall 2009 Model

$$(\text{Exam})ij = \beta_1 + \beta_2(\text{Occasion})_i + \beta_3(\text{BLS})_{ij} + \beta_4(\text{EnvP})_i + \beta_5(\text{Ability})_{ij} + \beta_6(\text{Support})_{ij} + \beta_7(\text{Engineering})_i + \beta_8(\text{Physci\_Math})_i + \beta_9(\text{Humanities})_i + \beta_{10}(\text{Undeclared})_i + \beta_{11}(\text{Othermajor})_i + \beta_{12}(\text{SES\_Wealthy})_i + \beta_{13}(\text{SES\_Uppmiddle})_i + \beta_{14}(\text{SES\_Working})_i + \beta_{15}(\text{SES\_Low})_i + \beta_{16}(\text{Chinese})_i + \beta_{17}(\text{Eastindianpakistani})_i + \beta_{18}(\text{Korean})_i + \beta_{19}(\text{Southeastasian})_i + \beta_{20}(\text{Otherasian})_i + \beta_{21}(\text{Mexican\_Black})_i + \beta_{22}(\text{Mixed})_i + \beta_{23}(\text{Otherethnicity})_i + \beta_{24}(\text{Female})_i + \zeta_j + \varepsilon_{ij}$$

j=occasion, i=individuals, $\zeta_j$ is a random intercept for student j

Analysis of Fall 2010 data was performed to determine repeatability of the findings from Fall 2009. The variables for Ability and Support were created as outlined above, creating an additional support variable to separate family and school based support (Support_School). The model below represents model 6 in the results, Table 14. Model 5 is the same as Model 6 except it does not include the Envp_Equity term.

Fall 2010 Model

$(Exam)ij = \beta_1 + \beta_2(Occasion)_i + \beta_3(EnvP)_i + \beta_4(Ability)_{ij} + \beta_5(Support)_{ij} + \beta_6(Support\_School)_{ij} + \beta_7(Envp\_Equity)_{ij} + \beta_8(Engineering)_i + \beta_9(Physci\_Math)_i + \beta_{10}(Humanities)_i + \beta_{11}(Undeclared)_i + \beta_{12}(Othermajor)_i + \beta_{13}(SES\_Wealthy)_i + \beta_{14}(SES\_Uppmiddle)_i + \beta_{15}(SES\_Working)_i + \beta_{16}(SES\_Low)_i + \beta_{17}(Chinese)_i + \beta_{18}(Eastindianpakistani)_i + \beta_{19}(Korean)_i + \beta_{20}(Southeastasian)_i + \beta_{21}(Otherasian)_i + \beta_{22}(Mexican\_Black)_i + \beta_{23}(Mixed)_i + \beta_{24}(Otherethnicity)_i + \beta_{25}(Female)_i + \zeta_j + \varepsilon_{ij}$

j=occasion, i=individuals, $\zeta_j$ is a random intercept for student j

## Results

*Descriptive Statistics*

The descriptive statistics for each belief, perception, interaction, and exam variable are shown below. Descriptive statistics for demographic dummy variables used for control were shown earlier in Table 7.

**Table 9: Descriptive statistics for continuous student beliefs and perceptions variables.** Mean (M), standard deviation (SD), and Cronbach alpha (alpha) computed from responses are shown. ($N_{2009}$=428 ; $N_{2010}$=597)

| Variable | Fall 2009 | | | Fall 2010 | | |
|---|---|---|---|---|---|---|
| | **M** | **SD** | **alpha** | **M** | **SD** | **alpha** |
| **Ability** | | | | | | |
| Occasion 1 | 2.76 | 0.56 | 0.83 | 2.51 | 0.58 | 0.90 |
| Occasion 2 | 2.47 | 0.67 | 0.86 | 2.28 | 0.66 | 0.91 |
| Occasion 3/4 | 2.36 | 0.67 | 0.86 | 2.25 | 0.64 | 0.91 |
| **Support** | | | | | | |
| Occasion 1 | 3.21 | 0.45 | 0.67 | 3.29 | 0.40 | 0.71 |
| Occasion 2 | 3.17 | 0.47 | 0.71 | 3.28 | 0.43 | 0.74 |
| Occasion 3/4 | 3.21 | 0.49 | 0.75 | 3.29 | 0.42 | 0.73 |
| **Support_School** | | | | | | |
| Occasion 1 | | | | 3.12 | 0.52 | 0.69 |
| Occasion 2 | | | | 3.18 | .053 | 0.72 |
| Occasion 3/4 | | | | 3.17 | .055 | 0.74 |
| **Envp_Equity** | | | | | | |
| Occasion 2 | | | | 3.76 | 0.77 | 0.90 |
| Occasion 3/4 | | | | 3.75 | .081 | 0.92 |
| **BLS** | | | | | | |
| Occasion 1 | 3.08 | 0.38 | 0.71 | | | |
| Occasion 2 | 3.05 | 0.42 | 0.77 | | | |
| Occasion 3/4 | 3.00 | 0.43 | 0.75 | | | |

**Table 10: Descriptive statistics for dichotomous student perception variable.**
Number of students (N), and percent of sample population (%) represented by each response option are shown. ($N_{2009}$=428 ; $N_{2010}$=597)

| Variable | Category | Fall '09 | | Fall '10 | |
|---|---|---|---|---|---|
| | | N | % | N | % |
| **EnvP** | Expressed Concern (1) | 121 | 28.3 | 167 | 28.0 |
| | Did not express concern (0) | 307 | 71.7 | 430 | 72.0 |

**Table 11: Descriptive statistics for interactions terms created.**
Mean (M), and standard deviation (SD) computed from responses are shown. ($N_{2009}$=428 ; $N_{2010}$=597)

| Variable | Fall 2009 | |
|---|---|---|
| | M | SD |
| **Suppability** | | |
| Occasion 1 | 8.91 | 2.42 |
| Occasion 2 | 7.90 | 2.64 |
| Occasion 3/4 | 7.65 | 2.65 |
| **Envpability** | | |
| Occasion 1 | 0.80 | 1.30 |

**Table 12: Descriptive statistics for response variables, exam scores.**
Minimum (Min), maximum (Max), mean (M), and standard deviation (SD) computed from responses are shown. ($N_{2009}$=428 ; $N_{2010}$=597)

| Variable | Fall 2009 | | | | Fall 2010 | | | |
|---|---|---|---|---|---|---|---|---|
| | Min | Max | M | SD | Min | Max | M | SD |
| **Exam1** | 0.3 | 99.8 | 53.7 | 27.5 | 0.3 | 99.3 | 50.4 | 28.0 |
| **Exam2** | 0.7 | 99.9 | 53.8 | 27.6 | 0.9 | 100 | 52.1 | 27.8 |
| **Exam4** | 1.7 | 98.7 | 55.3 | 27.6 | 1.7 | 99.7 | 52.0 | 27.5 |
| **ExamFinal** | 2 | 99.8 | 56.3 | 27.9 | 3.1 | 100 | 54.9 | 27.1 |

*Fall 2009 Model Estimates*
The hierarchical linear models used (Model 1 - 4) estimated how student beliefs, perceptions, demographic, and interaction variables related to student exam scores (refer to Table 13 for results and Table 8 for a summary of variables). The effect of each variable in the model was evaluated based on the coefficient computed and the corresponding p-value, or level of significance. Variables were considered to be significant if the p-value corresponding to their model coefficient was <0.05, or 5%. Other variables are controlled for when reporting coefficients and interpretations for each variable. The findings from these models are given below. Explanations behind these findings are given later in the discussion section.

*Fall 2009 Model comparisons:* Model 3 and Model 4 include interaction terms for student beliefs in their ability with perceptions of the classroom environment and perception of external support, respectively. In each of these models, the coefficient for the interaction term is not significant at the 5% level. Given the small coefficient, or effect, of these interaction terms in each of the models and the fact that they are not significant at the 5% level, these models were not considered as the final model. Model 1 and Model 2 differ by the inclusion of student beliefs about learning science (BLS) in Model 2. Because the BLS variable was found to be significant at the 5% level, yet there were some concerns over what belief this subscale was representing, both of these models were considered when determining the effects of each belief and perception.

*Fall 2009 Student Beliefs and Perceptions:* Student beliefs in their academic ability in chemistry is found to have the most significant effect on course performance.

- Student beliefs in their academic ability in chemistry shows a positive and significant coefficient. As student beliefs in their ability in chemistry increases, the corresponding exam score in the course increases as well ($\beta_{\text{Model 1}} = 14.08$, $p<0.001$; $\beta_{\text{Model 2}} = 12.62$, $p<0.001$).
- A negative and significant coefficient for student self report of perceptions of external support is found in Model 2 when student beliefs about learning science is also included. In Model 2, as student perceptions of external support increases, the corresponding exam score decreases ($\beta_{\text{Model 2}} = -3.65$ , $p = 0.013$).
- When included in Model 2 student beliefs about learning science shows a positive and significant coefficient. This demonstrates how a more dynamic view of science results in an increased exam score ($\beta_{\text{Model 2}} = 8.08$, $p<0.001$).
- Student perceptions of the classroom environment does not significantly predict course exam scores at the 5% level.

*Fall 2009 Student Demographic Characteristics*

- *Major*: Only one dummy variable representing student major shows a positive and significant coefficient. Engineering majors ($\beta_{\text{Model 1}} = 10.08$, $p<0.001$; $\beta_{\text{Model 2}} = 10.30$, $p<0.001$) mean exam scores are higher than the reference, Life Science majors.
- *Socio-Economic Status*: Two dummy variables representing student socio-economic status (SES) have a negative and significant coefficient. When compared with students of SES middle-class, students of SES working-class ($\beta_{\text{Model 1}} = -14.50$, $p<0.001$; $\beta_{\text{Model 2}} = -14.59$, $p<0.001$), and of low-income families ($\beta_{\text{Model 1}} = -5.55$, $p=0.041$; $\beta_{\text{Model 2}} = -6.04$, $p=0.023$), have lower mean exam scores.
- *Ethnicity*: Two dummy variables representing ethnicities in Model 1 and one in Model 2 showed a negative and significant coefficient. Mexican/African-American students ($\beta_{\text{Model 1}} = -14.86$, $p=0.008$; $\beta_{\text{Model 2}} = -14.38$, $p=0.009$) have lower mean exam scores than that of the reference, White students. Students of Mixed ethnicity ($\beta_{\text{Model 1}} = -6.18$, $p=0.035$) in Model 1 have a lower mean exam score with reference to students who are White.

**Table 13: Summary of Maximum Likelihood Estimates for Student Beliefs and Perceptions Effects on Exam Performance in Fall 2009 (Models 1-4).**
Coefficients (Coef) and standard errors (SE) computed in analysis of each model are included for each variable. ($N_{2009}$=428)

| | **Model 1** | | **Model 2** | | **Model 3** | | **Model 4** | |
|---|---|---|---|---|---|---|---|---|
| | Coef | SE | Coef | SE | Coef | SE | Coef | SE |
| Constant | 21.99** | 5.92 | 6.44 | 6.69 | 6.37 | 6.76 | 9.96 | 15.38 |
| Occasion2 | 2.05* | 0.65 | 1.95* | 0.65 | 1.95* | 0.65 | 1.94* | 0.65 |
| Occasion3 | 1.78** | 0.34 | 1.80** | 0.33 | 1.80** | 0.34 | 1.80** | 0.33 |
| Occasion4 | 1.61** | 0.27 | 1.63** | 0.27 | 1.63** | 0.27 | 1.63** | 0.27 |
| **Beliefs & Perceptions** | | | | | | | | |
| Ability | 14.08** | 1.19 | 12.62** | 1.23 | 12.64** | 1.28 | 11.14 | 5.96 |
| Support | -2.06 | 1.45 | -3.65* | 1.47 | -3.64* | 1.47 | -4.75 | 4.58 |
| EnvP | -0.09 | 1.83 | -0.04 | 1.78 | 0.53 | 8.75 | -0.03 | 1.78 |
| BLS | | | 8.08** | 1.75 | 8.08** | 1.75 | 8.08** | 1.75 |
| **Interactions** | | | | | | | | |
| Envp_Ability | | | | | -0.20 | 3.06 | | |
| SuppAbility | | | | | | | 0.46 | 1.81 |
| **Demographics** | | | | | | | | |
| Engineering | 10.08** | 2.17 | 10.30** | 2.12 | 10.30** | 2.12 | 10.30** | 2.11 |
| Physci_Math | -0.49 | 5.39 | -1.92 | 5.27 | -1.88 | 5.30 | -1.95 | 5.27 |
| Humanities | 0.22 | 4.45 | 0.72 | 4.35 | 0.73 | 4.35 | 0.72 | 4.35 |
| Undeclared | 1.19 | 2.39 | 0.66 | 2.33 | 0.66 | 2.33 | 0.64 | 2.33 |
| Othermajor | -4.05 | 3.69 | -3.54 | 3.60 | -3.55 | 3.60 | -3.51 | 3.60 |
| SES_Wealthy | -5.70 | 5.17 | -5.69 | 5.05 | -5.72 | 5.07 | -5.68 | 5.05 |
| SES_Uppmiddle | 1.91 | 1.89 | 1.56 | 1.84 | 1.56 | 1.84 | 1.56 | 1.84 |
| SES_Working | -14.50** | 2.93 | -14.59** | 2.87 | -14.59** | 2.87 | -14.62** | 2.87 |
| SES_Low | -5.55* | 2.72 | -6.04* | 2.66 | -6.04* | 2.66 | -6.01* | 2.66 |
| Chinese | 2.95 | 2.22 | 3.16 | 2.17 | 3.16 | 2.17 | 3.18 | 2.17 |
| Eastindianpakistani | -0.04 | 3.60 | -0.23 | 3.52 | -0.22 | 3.52 | -0.24 | 3.52 |
| Korean | 1.42 | 2.99 | 2.34 | 2.93 | 2.32 | 2.94 | 2.33 | 2.93 |
| Southeastasian | -5.34 | 4.39 | -5.27 | 4.29 | -5.28 | 4.29 | -5.27 | 4.29 |
| Otherasian | 5.28 | 3.71 | 4.95 | 3.62 | 4.94 | 3.62 | 4.93 | 3.62 |
| Mexican_Black | -14.86* | 5.61 | -14.38* | 5.48 | -14.39* | 5.48 | -14.35* | 5.48 |
| Mixed | -6.18* | 2.93 | -5.59 | 2.87 | -5.60 | 2.87 | -5.59 | 2.87 |
| Otherethnicity | -0.48 | 4.60 | -0.11 | 4.49 | -0.11 | 4.49 | -0.14 | 4.49 |
| Female | -2.06 | 1.79 | -2.47 | 1.75 | -2.47 | 1.75 | -2.48 | 1.75 |
| **Random Effects** | | | | | | | | |
| Between-student | 13.46 | 0.72 | 12.99 | 0.71 | 12.99 | 0.72 | 12.98 | 0.71 |
| Within-student | 18.40 | 0.37 | 18.40 | 0.37 | 18.40 | 0.37 | 18.40 | 0.37 |

* p<0.05 ** p<0.001

Analysis of Fall 2009 measures indicate student beliefs in their academic abilities has the most significant effect on exam performance. Interactions between student beliefs and perceptions were not found to be significant at the 5% level.

*Fall 2010 Model Estimates*

The hierarchical linear models used (Model 5 & 6) estimated how student beliefs, perceptions, and demographic characteristics related to student exam scores (refer to Table 14 for results and Table 8 for a summary of variables). The effect of each variable in the model was evaluated based on the coefficient computed and the corresponding p-value, or level of significance. Variables were considered to be significant if the p-value corresponding to their model coefficient was $<0.05$, or 5%. Other variables are controlled for when reporting coefficients and interpretations for each variable.

Interaction terms between student beliefs and perceptions were not included in analysis of the Fall 2010 data since their effects were not found to be significant at the 5% level during the analysis of Fall 2009 responses. Comparing estimates from measures taken in Fall 2009 to those from Fall 2010 similarities can be found to strengthen our determination of the effects for specific student beliefs and perceptions.

*Fall 2010 Model comparisons:* Models 5 and 6 each include measures of student beliefs in their ability, perceptions of external support, and perceptions of the classroom environment. Unlike Fall 2009, the Fall 2010 measure of student perceptions of support is split into two separate measures for family based support and school/peer centered support. Model 5 is similar to Model 1 in Fall 2009, except for the inclusion of two perceptions of support variables. Model 6 has the addition of a perception of classroom equity measure, which was not included in Fall 2009.

*Fall 2010 Student Beliefs and Perceptions:* Student beliefs in their academic ability and perceptions of the classroom environment are found to have significant effects on exam performance in Fall 2010. Findings from measures of student perceptions of the classroom environment contradict each other between a more general measure of perception (EnvP) and a specific equity measure (Envp_Equity).

- Similar to Fall 2009, student beliefs in their academic ability in chemistry shows a positive and significant coefficient. As student beliefs in their ability in chemistry increases, the corresponding exam score in the course increases as well ($\beta_{\text{Model 5}} = 11.37$, $p<0.001$; $\beta_{\text{Model 6}} = 15.67$, $p<0.001$).
- Students self-report of perceptions of external support, family and school based, do not have a significant effect on their course exam scores at the 5% level. This agrees with findings in Fall 2009 Model 1 when BLS was not included.
- Unlike Fall 2009, Fall 2010 Model 5 shows a positive and significant coefficient for student perceptions of the classroom environment. Students who indicate concern for the classroom environment ($\beta_{\text{Model 5}} = 4.01$, $p=0.016$) have a higher mean exam score than students who do not indicate a concern.
- In Model 6 when student perceptions of the classroom equity was included, there is a significant and positive coefficient for the Equity variable. Students exam scores will increase with an increased perception of the equity in the class ($\beta_{\text{Model 6}} = 3.55$, $p<0.001$).

*Fall 2010 Demographic characteristics:*

- *Major*: Same as Fall 2009, only one dummy variable representing student major shows a positive and significant coefficient in Fall 2010. Engineering majors' ($\beta_{Model\ 5} = 7.57$, $p<0.001$; $\beta_{Model\ 6} = 6.68$, $p=0.002$) mean exam scores are higher than the reference, Life Science majors.
- *Socio-Economic Status*: The same two dummy variables representing student socio-economic status (SES) have negative and significant coefficients in both Fall 2009 and Fall 2010 Model 5. Model 6 in Fall 2010 only has one SES category dummy variable that is significant. When compared with students of SES middle-class, students of SES working-class ($\beta_{Model\ 5} = -6.85$, $p=0.011$; $\beta_{Model\ 6} = -5.95$, $p=0.030$) and low-income ($\beta_{Model\ 5} = -7.60$, $p=0.014$) have lower mean exam scores.
- *Ethnicity*: Same as Fall 2009, in Fall 2010 Mexican/African-American students ($\beta_{Model\ 5} = -20.80$, $p<0.001$; $\beta_{Model\ 6} = -19.54$, $p<0.001$) have lower mean exam scores with reference to White students. While students of Mixed ethnicity show no significant difference in mean exam scores from White students; in Fall 2010 students of Chinese ethnicity show a positive and significant coefficient. Students of Chinese ethnicity ($\beta_{Model\ 5} = 4.93$, $p=0.021$; $\beta_{Model\ 6} = 5.46$, $p=0.012$) have a higher mean exam score compared with the reference, students who are White. Fall 2010 has an additional negative and significant coefficient for the dummy variable for being Female.
- *Gender*: In Fall 2010, students who are female ($\beta_{Model\ 5} = -5.89$, $p<0.001$; $\beta_{Model\ 6} = -4.41$, $p=0.007$) have lower mean exam scores compared with male students.

**Table 14: Summary of Maximum Likelihood Estimates for Student Beliefs and Perceptions Effects on Exam Performance in Fall 2010 (Models 5-6).** Coefficients (Coef) and standard errors (SE) computed in analysis of each model are included for each variable. ($N_{2010}$=597)

| | **Model 5** | | **Model 6** | |
|---|---|---|---|---|
| | Coef | SE | Coef | SE |
| Constant | 22.32** | 6.02 | 9.17 | 6.63 |
| Occasion2 | 2.17** | 0.54 | | |
| Occasion3 | 1.14** | 0.27 | 0.85 | 0.25 |
| Occasion4 | 1.48** | 0.22 | 0.64* | 0.20 |
| **Beliefs & Perceptions** | | | | |
| Ability | 11.37** | 1.05 | 15.67** | 1.17 |
| Support | 0.31 | 1.58 | -0.55 | 1.79 |
| Support_School | -0.20 | 1.19 | -1.10 | 1.39 |
| EnvP | 4.01* | 1.67 | 2.47 | 1.70 |
| Envp_Equity | | | 3.55** | 0.87 |
| **Demographics** | | | | |
| Engineering | 7.57** | 2.12 | 6.68* | 2.16 |
| Physci_Math | 2.96 | 4.25 | -0.77 | 4.34 |
| Humanities | -4.76 | 3.50 | -5.98 | 3.56 |
| Undeclared | 0.92 | 2.29 | 0.76 | 2.33 |
| Othermajor | -5.64 | 3.39 | -5.21 | 3.45 |
| SES_Wealthy | 0.25 | 4.81 | -0.35 | 4.90 |
| SES_Uppmiddle | 2.86 | 1.70 | 1.37 | 1.73 |
| SES_Working | -6.85* | 2.68 | -5.95* | 2.73 |
| SES_Low | -7.60* | 3.08 | -5.38 | 3.14 |
| Chinese | 4.93* | 2.13 | 5.46* | 2.18 |
| Eastindianpakistani | 1.19 | 3.61 | 1.26 | 3.68 |
| Korean | 1.53 | 3.24 | 2.18 | 3.31 |
| Southeastasian | -6.41 | 3.38 | -5.71 | 3.43 |
| Otherasian | 5.71 | 3.61 | 5.17 | 3.68 |
| Mexican_Black | -20.80** | 4.25 | -19.54** | 4.33 |
| Mixed | 1.75 | 2.52 | 1.77 | 2.57 |
| Otherethnicity | -1.90 | 3.20 | -2.83 | 3.26 |
| Female | -5.89** | 1.60 | -4.41* | 1.64 |
| **Random Effects** | | | | |
| Between student | 15.29 | 0.63 | 15.23 | 0.64 |
| Within student | 18.22 | 0.31 | 16.96 | 0.35 |

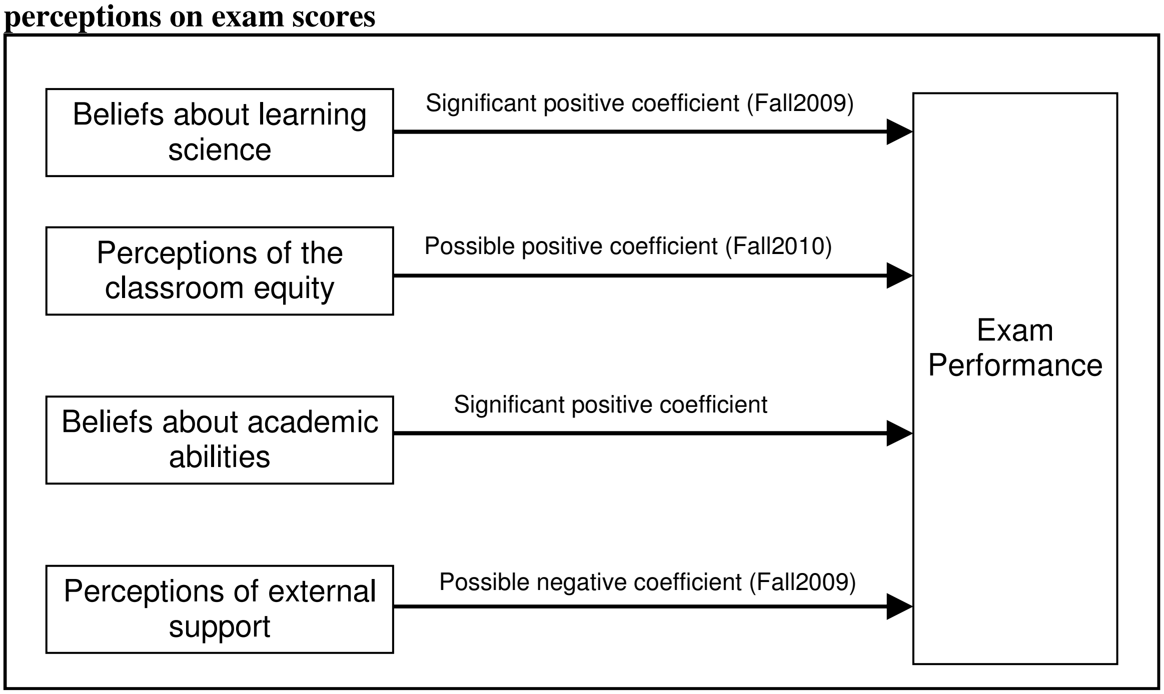
* $p<0.05$ ** $p<0.001$

**Discussion/Implications**

Student beliefs about their academic abilities in chemistry was found to have a significant effect on exam performance in both Fall 2009 and Fall 2010. As student beliefs in their ability in chemistry increases, the corresponding exam score in the course increase as well ($p<0.001$). From analysis of measures from Fall 2009, student beliefs about learning science shows a positive and significant coefficient. A more dynamic view of science resulted in an increased exam score ($p<0.001$). Additionally in Fall 2009, a negative and significant coefficient for student self report of perceptions of external support was found when included in analysis along with student beliefs about learning science. As student perceptions of external support increases, the corresponding exam score decreases ($p = 0.013$). Unlike Fall 2009, analysis of Fall 2010 responses found a significant coefficient for student perceptions of the classroom environment. When student perceptions of the classroom equity was included, there was a significant and positive coefficient for the Equity variable. Student's exam scores increase with an increased perception of the equity in the class ($p<0.001$). Except for student perceptions of support, these findings agree with current literature. These effects and their similarities or differences from literature findings are narrated below.

Figure 9 illustrates the possible effects found, based on comparison of results across models, determined from comparison of results from Fall 2009 and Fall 2010.

**Figure 9: Illustration of logic model indicating effects found for student beliefs and perceptions on exam scores**




These results suggest that the measure of student beliefs in their academic ability in chemistry is a significant predictor of their course exam scores in introductory chemistry. This is confirmed through the repeated positive and significant coefficient for the Ability variable in two separate semesters, Fall 2009 and 2010. Overall, when comparing results from Model 1 in Fall 2009 and Model 5 in Fall 2010, which contain comparable variables, the Ability variable consistently has a positive and significant effect on student exam scores. The similarity in results between Model 1 in Fall 2009 and Model 5 in Fall 2010 strongly supports the idea that student beliefs in his/her ability significantly affects his/her course performance in introductory chemistry.

Model 2 in Fall 2009 also suggests a possible effect from student beliefs about learning science on course exam scores. To confirm this effect, the beliefs about learning science measure would have to be strengthened to ensure the items were all measuring the desired belief. The negative and significant effect found for student perceptions of external support when beliefs about learning science was also included (Model 2) may be explained by student goals or level of interest in the course. Since the items measuring student beliefs about learning science include items that encompass goals in the course (how important the grade is), perceptions of support may influence their tendency to act on these goals. For example if a student is not very interested in learning the course content but perceives a high level of support, his/her fear of failure may be lower which ultimately would make him/her focus less on learning for this course. This may consequently result in a lower exam score. Oppositely, the same student, perceiving less support and therefore feeling more pressure to perform despite his/her low learning goals, may receive a higher exam score due to his/her increased fear of failure.

The findings in Fall 2010 of a significant effect of student perceptions of the classroom environment (Model 5) may be due to the difference in timing of the first survey between semesters. The initial survey was administered in closer proximity to the first exam in the course (a week later into instruction) during Fall 2010. This may also help to explain results in Fall 2009 of perceptions of support, with students who feel more pressure due to a negative classroom perception becoming more focused and therefore performing higher on exams.

The effects from the demographic categories used for control during Fall 2009 and Fall 2010 are similar. Fall 2010 has two added positive effects that need to be explored in future research.

This analysis expands on the current literature by including all four beliefs and perceptions in a single model, as well as directing focus on achievement within a college level introductory chemistry course. The effects summarized in Figure 9 show many similarities with those found in previous studies. Positive correlations between student beliefs about learning science, perceptions of the classroom equity, and beliefs about academic ability mirror those predicted from previous findings (Ali et al., 2008; House, 1995; Songer & Linn, 1991). Finding that a more dynamic view of science resulted in an increased exam score is in agreement with the previous literature reviewed on this belief (Lederman et. al, 2002; Rosenberg et al., 2006; Songer & Linn, 1991; Stathopoulous & Vosniadou, 2007). Support for our hypothesis that increased beliefs about academic abilities would have a positive effect on course performance mirrors previous findings by House (1995) and Nieswandt (2007).

The interaction terms considered and the effects found for student perceptions of support conflict with existing findings. Possible effects between student perceptions and beliefs about their academic abilities were not found. This may be due in part to the response population in this study. Britner and Pajares (2006) focused on sources influencing student beliefs about their academic abilities for middle school students. Middle school students have not yet been allowed to choose their selection of courses and so this population may include individuals who would not select to take an introductory chemistry course once at the college level. In contrast, the population in this study was representative only of those selecting to study science when entering college. Additionally, previous findings may have cued students to refer to the same course in evaluating their perceptions of the classroom and beliefs about academic ability. Items in this survey cued students to think only of the current course in evaluation of perceptions of the classroom equity yet cued for evaluation of past experiences along with the current course in evaluation of academic ability.

The other effect that did not reflect previous findings was the negative effect of perceptions of external support on exam scores. Effects found by Roman et al. (2008) considered university students from a variety of majors and did not consider achievement in a single course. Measuring effort and achievement by student GPA did not focus this measure on the common course all students were taking (Roman et al., 2008). Students represented in this analysis were evaluated for their achievement through exam scores in the introductory chemistry course. This focus of achievement in chemistry captured direct effects of support perception for the course of interest. This focus of achievement in chemistry distinguishes students who may be, on average, succeeding in college based on overall GPA, yet not demonstrating the same level of success in the chemistry course. While perceptions of external support may, on average, increase overall performance in college, it is not concluded to determine success in every course.

The agreement between effects found in previous studies with three of the four beliefs and perceptions considered demonstrates further reason to support these findings. Further exploration is warranted to explain the reasons behind the negative effects found from perception of external support on exam scores. Further exploration may strengthen these findings. The effects found between beliefs and perceptions in the logic model help to support the hypothesis motivating this research. While all students in this course have the ability to succeed, their beliefs and perceptions are found to have a significant influence on the level of success they may realize in the course.

## Chapter 6: Development and Evaluation of the Use of Resources Framework in Chemistry

### Introduction

This chapter describes the development of the Use of Resources Framework in Chemistry and the evaluation of the behaviors outlined by this framework. Specifically, this chapter answers the second research question, "What study strategies do students demonstrate when using resources for the course and which behaviors prove most successful in developing scientific thinking?" To answer the first part of this research question, the Use of Resources Framework categorizes common behaviors students employ towards their use of resources within the context of an introductory chemistry course. These behaviors are then correlated with exam performance in the same course. The characterization and evaluation of the degree to which students use resources effectively extend the current literature by including an evaluation of independent learning outside the classroom which has resulted from a modified course curriculum.

### Rationale

Numerous studies of how to improve student learning of chemistry concepts have been conducted. Most of these studies focus on classroom instructional methods at the high school level. For example, studies by Linn, Davis, and Eylon (2004) have shown increased learning from curricular approaches incorporating principles from the knowledge integration framework for instruction within the classroom. In a large university lecture course however, a substantial amount of student learning happens outside of the classroom. Thus, existing research on classroom instructional methods may not be able to explain the processes involved in student learning outside the classroom.

Previous studies on self-regulated learning attempt to close the gap between the current understanding of classroom-based learning and more independent learning outside of the classroom. Pintrich (1995, p.5) proposes that “self-regulated learning involves the active, goal-directed, self-control of behavior, motivation, and cognition for academic tasks by an individual student.” His studies primarily explore three dimensions of student learning: their observable behavior, their motivation and affect, and their cognition (Pintrich, 1995). Self-regulated learning research, however, does not characterize how learning outside of a large university lecture setting is happening; what takes place when students are taught utilizing a curriculum modified to focus on creating students who are critical thinkers and adept at making connections between the concepts presented in the course. To address this need, this study examines the behaviors that these students, taught with this modified curriculum, exhibit while studying outside the lecture course.

To better understand how students learn chemistry, we reviewed several curricular approaches developed and evaluated for their effective use within the classroom. These approaches have similarities with elements of the Knowledge Integration Framework for Instruction (Linn et al., 2004). The modified curriculum used during this study is aligned with these approaches. These approaches, developed for use within the classroom, indicated effective development of scientific thinking. The approaches include students’ use of explanations (Hunt & Minstrell, 1994; Teichert & Stacy, 2002), cognitive apprenticeship or training (Chiu, Chou, & Chai-Ju Liu, 2002), and the MORE thinking frame (Tien, Teichert, & Rickey, 2007). Additionally, various computer modules, which integrate visualization tools that allow students to learn through exploration of the models, have also proven effective (Levy & Wilensky, 2009; Linn, Lee, Tinker, Husic, & Chiu, 2006; Pallant & Tinker, 2004).

One common theme in the aforementioned approaches is the emphasis on instruction that more explicitly addresses the molecular level models to explain concepts, along with prompting students to explain phenomena using these molecular level ideas. These classroom-based approaches helped inform our current work since behaviors incorporating comparable strategies may prove effective for students when studying outside the classroom. The hypothesis in this study is that behaviors containing elements of the curricular approaches found effective in a classroom may have similar success when used by students studying independently.

Based on this hypothesis and the curricular approaches reviewed, students who engage with the concepts on the molecular level, creating and evaluating molecular level models to explain the ideas they are learning, may prove more successful in the development of scientific thinking. Students who make their thinking visible to themselves and others, through explanations that exchange ideas and evaluation of these ideas, may have more success in the course. The use of strategies that help students guide their own learning and actively evaluate and critique new ideas they are presented for accuracy may result in higher exam scores.

Once these behaviors are defined and categorized, the question of what behaviors are proving most successful in the student's use of course resources to develop scientific thinking can be explored. Do students who apply strategies, found to be successful within the classroom, become more successful in developing scientific thinking on their own when they use these strategies as they study outside the classroom? Furthermore, do these strategies, applied to studying outside of the classroom, correlate with their performance in exams? The identification and evaluation of independent learning behaviors from students instructed with modified curriculum will broaden the current literature because the extent that these strategies translate to use outside the classroom as well as their effectiveness outside the classroom will be evaluated.

**Methods**

Interviews collected from a stratified random sample of 61 students at three time points during the semester were evaluated. A comparison of demographic data between the course population and the interview sample revealed that the subset of 61 students was representative of the student population. Interviews explored the topic of how they were studying for the course. Collection of interviews was chosen over the survey since interviews allowed for a more complete understanding of student behaviors. Responses describing student behaviors when using available resources were categorized to develop the Use of Resources Framework for Chemistry. These behavior categories were then evaluated for their ability to distinguish exam performance. The analysis resulted in an increased understanding of what types of behaviors proved more effective for students' development of scientific thinking when studying outside the classroom.

Characterization of student behaviors towards use of resources focused on portions of the interview responses in which students described their approach to studying for exams, or the course in general. Figure 10 shows the interview prompts from the portions of the interviews used in this evaluation. Since the interviews were semi-structured, these questions were asked as part of the interview protocol, followed by questions further exploring each student's specific response to the original question.

**Figure 10: Questions relating to use of resources from interview protocols**

| Interview | Portion of Interview Protocol Used for analysis |
|---|---|
| Interview 1<br><br>After Exam 1 | **Q3.** How did you feel about the grade you received on this past exam?<br>Did you think it reflected your ability?<br>**Q4:** Tell me about how you studied for this past exam.<br>If unclear followed up with prompts such as:<br>• Did you work with others?<br>• Did you work problems from the book or OWL (how did you use them?)<br>• Did you take past exams?<br>• Did you review the book, notes, etc.? (how did you use them?)<br>• Did you go to the review sessions?<br>• Did you go to office hours?<br>• Student Learning Center mock midterm<br>What do you think helped you the most in studying for this exam?<br>**Q5:** Do you plan to make any changes in your study habits for the next midterm?<br>What changes? Why? |
| Interview 2<br><br>After Exam 2 | **Q1:** Now that you have had a little more time in the course how do you feel about your preparation and ability now?<br>**Q2:** Generally in the course have you changed your study habits at all?<br>• Why did you make these changes?<br>• How have these changes helped you?<br>• Why weren't you doing this from the start?<br>• Do you study with other students from the class?<br>**Q3:** Was your performance on this midterm what you had expected going into the exam?<br>**Q4.** How did you feel about the grade you received on midterm 2?<br>Did you think it reflected your ability on this material?<br>**Q5:** Tell me how you prepared for this midterm.<br>• How was this different from how you prepared for the first midterm?<br>• Why did you make these changes?<br>• How did these changes affect your performance on the exam?<br>• What do you think helped you the most in studying for this exam?<br>• Do you plan to make any further changes in studying for midterm 3? |
| Interview 3<br><br>After Exam 4 | **Q3:** Looking back, how do you think your knowledge from previous science courses influenced you this semester?<br>**Q4:** What are the most significant changes you have made in your study habits this semester?<br>• Why were they significant<br>• What prompted you to make these changes<br>• When did you make these changes<br>• Do you feel like you are memorizing a lot this semester<br>**Q5:** Was your performance in this class so far what you had expected going into the course?<br>**Q7:** I notice that your midterm scores have changed over the semester, what do you think caused this?<br>**Q8:** Describe to me what a "good" chem. 1A student looks like…..<br>**Q9:** Has this class changed how you think about chemistry at all? |

Once the Use of Resources Framework for Chemistry was developed, student responses to these prompts were coded using the levels outlined in the framework. Each student was assigned codes for each of the subcategories (metacognition, text, problem solving, seeking others or peers) as well as an overall resource use code at each of the three time-points. If a given student did not make any reference to using resources in a given resource category during an interview, they were not given a code for that resource at that time-point. Once all the codes were assigned for their use of resources, student exam scores were added to the dataset. The final set of data includes codes for student use of resources and exam scores. This final dataset was used in the analysis.

The effects of student use of resources on exam scores were evaluated in two ways. First, students were divided into two categories, high and low resource use. These groups were then compared for their mean exam scores over the semester. Second, students were divided into high and low exam scores and evaluated for their mean resource use over the semester.

To further evaluate the resource use categories, a one-way analysis of variance (ANOVA) was conducted on the overall resource use code and for each resource subcategory. Exam score was the response variable for each of these tests and resource use codes (overall and each subcategory) were the factor in the one-way ANOVA. Three time points corresponding to when students were interviewed during the semester were considered. ANOVA tests conducted for each time point used the corresponding resource use codes and exam score. An additional exam (exam 3) was administered between time points 2 and 3, but this was not included for analysis since no other measures were collected at this time. The final interviews were collected during the two week period between exam 4 and the final exam in the course (exam 5). Because these interviews had such close proximity to both exams, and asked students about their use of resources for each exam, the resource use codes assigned, based on the final interview, were used in evaluating both exam 4 and the final exam. This assumes that student use of resources was the same for each of these exams. This is believed to be a safe assumption given that the exams were administered within two weeks of each other, the interviews were conducted in the short time between them, and students were asked about each exam separately.

**Participants and Data Collection**

Participants were students enrolled in the introductory chemistry course at a large public university. This course enrolls approximately 1300 students each Fall semester. This course is designed for non-chemistry majors who need to take chemistry as a pre-med or major requirement.

On the evening of the first exam, students who had given consent to be interviewed were invited via email to participate in individual semi-structured interviews. Students were selected for interviews from those who responded to the invitation. To ensure a representative population, demographic data were examined as students scheduled their first interview. The demographic categories that were considered were ethnicity, gender, major, socio-economic status (SES) category, and first exam score. Exam scores were tracked by division into three performance categories: high, medium, and low. The sample of students scheduled to be interviewed were chosen to ensure that the sample was representative of the demographics of the entire class (see Table 15 for comparison). Selected students were scheduled for interviews to take place during the week after the exam. Exams were distributed to students during lab sections. Interviews were scheduled after each student attended his/her lab section that week to ensure he/she had been given time to review the exam prior to the interview. Interviews were conducted by two of the researchers involved with this study. Each selected student was assigned to an interviewer, who would interview him/her at each time-point. This ensured each student would be interviewed by the same individual for the duration of the study.

Follow-up interviews with these same students were conducted after the second and fourth exams to collect repeated reports of student behavior over the semester. These interviews were scheduled via email after each of the exams. The fourth exam was administered two weeks before the end of instruction, so interviews after the fourth exam were also considered an exit interview given its proximity to the end of the semester. All interviews were semi-structured, which allowed the students to expand on the main questions and explore the underlying issues or concerns. These interviews included questions exploring student behavior towards use of resources from the course, which prompted them to describe how they studied for the recent exam (see Appendix B for complete interview protocols).

**Table 15: Descriptive statistics for demographic information comparing the survey population from Fall 2009 with the sub-set selected for interview.**
Number of students (N), and percentage of sample population (%) represented, self reporting to be included in each demographic category for each sample population is included.

| Variable | Category | Fall '09 Sample | | Interview Group | |
|---|---|---|---|---|---|
| | | N | % | N | % |
| **Major** | Life Science | 225 | 52.6 | 27 | 44.3 |
| | Engineering | 94 | 22.0 | 14 | 23.0 |
| | Physical Science/Mathematics | 10 | 2.3 | 4 | 6.6 |
| | Humanities | 15 | 3.5 | 4 | 6.6 |
| | Undeclared | 62 | 14.5 | 8 | 13.1 |
| | Other | 22 | 5.1 | 4 | 6.6 |
| | | | | | |
| **SES** | Wealthy | 11 | 2.6 | 1 | 1.64 |
| | Upper-middle or professional middle | 165 | 38.6 | 30 | 49.2 |
| | Middle-class | 157 | 36.7 | 21 | 34.4 |
| | Working-class | 43 | 10.0 | 5 | 8.2 |
| | Low-income or poor | 52 | 12.1 | 4 | 6.6 |
| | | | | | |
| **Ethnicity** | Chinese/Chinese-American | 142 | 33.2 | 16 | 26.2 |
| | East Indian/Pakistani | 27 | 6.3 | 4 | 6.6 |
| | Korean/Korean-American | 47 | 11.0 | 2 | 3.3 |
| | South East Asian | 17 | 4.0 | 3 | 4.9 |
| | Other Asian | 25 | 5.8 | 4 | 6.6 |
| | Mexican/Mexican-American/African-American/Black | 10 | 2.3 | 3 | 4.9 |
| | White | 98 | 22.9 | 24 | 39.3 |
| | Mixed | 47 | 11.0 | 2 | 3.3 |
| | Other | 15 | 3.5 | 3 | 4.9 |
| | | | | | |
| **Gender** | Female | 264 | 61.7 | 34 | 55.7 |
| | Male | 164 | 38.3 | 27 | 44.3 |
| | | | | | |
| **Total** | | **428** | | **61** | |

## Framework Development
Initially a subset of ten student interviews were randomly chosen and reviewed to make notes of response characteristics and determine what sections of the interviews contained the most information on student use of resources. After selecting portions of the interviews to use, an initial framework was outlined. This framework began to describe student use of resources separated into four levels. To expand the descriptions in this framework, an additional randomly selected set of ten student interviews were watched and coded using this framework. During this process, the initial framework was revised to describe each level with more clarity based on the variety of responses identified.

Once the initial framework was developed, it was realized that students may exhibit different levels of use when utilizing different resource categories. This led to a framework expansion to describe how each of the four levels would be expressed. This separates out the following four resource categories: (1) metacognition; (2) use of text based resources; (3) solving problems; and (4) seeking help from others or working with peers. Using these categories, the remaining student interviews were coded for each of these four subcategories as well as an "overall use of resource" code indicating what level the student primarily expressed. The framework was refined as more interviews were coded to reflect new response characteristics.

Once all of the students had been coded for their use of resources at each time point, a second researcher used the framework to code a subset of ten randomly selected students. The second researcher highlighted any portions of the framework which were confusing and needed further clarification. Based on these comments the framework was revised to add clarity and students previously assigned codes were reviewed to reflect changes made to the framework.

Once the framework was finalized, the second researcher independently coded 21 randomly selected students, which represented 34% of the sample. Students were assigned codes for each of the resource categories as well as an overall resource use code at each time point. Figure 11 shows the directions that were used to help guide coders in the use of the framework.

**Figure 11: Directions given for coding of videos with the Use of Resources Framework in Chemistry**

| **Use of Resources Framework – Directions for video coding** |
|---|
| While watching each video assign codes for each of the categories listed: metacognition, text based resources, solving problems, and working with others.<br>When students reference each of these types of resources assign the code corresponding with the strategies they are describing.<br>Metacognition may be assigned while students are talking about how their performance relates to their understanding, how they view the course, or while they discuss their study habits. Some quotes may help to code for both metacognition as well as one of the other resource categories.<br>Not all categories need to be coded for each video, they are only coded if the student talks about it. If a type of resource is not mentioned the category is not coded for.<br>Once the video has been coded for within the individual categories, an overall use of resource code is assigned. This overall code is determined based on their individual category codes and how much they used each of the resources. If a category was not coded for since the student did not reference using this type of resource that category is not used to determine the overall code. The overall code is based only on categories the student used; they are not lowered or penalized for not using a particular resource. If a student used one category more than others, the overall code should reflect this giving more weight to the activities engaged in most often. For example, if a student mostly worked with peers and solved problems and those categories were both coded at a 3 level, yet they mention using the text occasionally for reference, which is coded as a 1, their overall code would still be a 3. The overall code in this scenario would only be lowered if text based resources, assigned a lower code than their other categories, was a type of resource they engaged with often and stressed in their studying. Using one category at a lower level should not lower their overall code if they did not use this type of resource often, and the other categories, used more often, were coded higher. The overall resource code reflects a weighted average of their resource use giving more weight to the types of resources which the given student used most often. |

**Inter-Rater Reliability for Use of Resource Framework Development**

The final Use of Resources Framework for Chemistry consists of four levels. Within each level there are descriptions for the four aspects of resource use described: (1) metacognition; (2) text; (3) problem solving; and (4) seeking others or peers. Two independent researchers' coding of a subset of 34% showed agreement >90% and Kappa >0.8 for assignment of the overall resource use code and each subcategory except for text-based resources. The full inter-rater results are outlined in Table 16 below.

**Table 16: Inter-rater reliability calculations for Use of Resources Framework.** Agreement and Cohen's Kappa computed based on comparison of code assignments.

| **Category** | **Agreement** | **Cohen's Kappa** |
|---|---|---|
| **Resource Code** | 98.4% | 0.96 |
| **Metacognition** | 93.7% | 0.88 |
| **Text** | 87.3% | 0.80 |
| **Problem Solving** | 98.4% | 0.97 |
| **Seeking others/Peers** | 98.4% | 0.96 |

The complete Use of Resources Framework for Chemistry is shown in Figure 12. This framework characterizes what students in each category may be doing at each level.

## Figure 12: Use of Resources Framework for Chemistry

| Level | Label | Description | Level of Metacognition | How this looks for different types of resources…… | | |
|---|---|---|---|---|---|---|
| | | | | **Text Based Resources (textbook / internet /lecture slides/webcasts)** | **Solving Problems (OWL / Past Exams/Textbook)** | **Seeking out Others (office hours / studying with peers/ SLC)** |
| 4 | Researcher | Taking in the information, questioning why this is true and how it helps to explain the world around them.<br><br>**Asking: How does this apply to what I see in the world?** | • Realize they can relate concepts to explain what they observe around them<br>• Assess for gaps in their knowledge of concepts through ability to make connections to larger themes (might assess ability to connect solutions to problems with larger picture presented) | • Read text to make connections between the concepts and underlying theories. Also questioning why these concepts are true and how they relate to the larger context.<br>• Clarify concepts through multiple sources to fill in gaps identified.<br>• Use the world around them as a resource | • Evaluate how the model works<br>• Use what they observe in the world around them to confirm if given solutions make sense<br>• Work out past exam questions, then confirming answer with the solution key, and then exploring how this relates to explain phenomena in the world around them (what else this relates to) | • Talk with peers about larger topics/concepts to integrate knowledge<br>• Rotate amongst peers as "teachers" to explain concepts to peers and asking for others to clarify when unclear (back and forth interplay to further clarify concepts) |
| 3 | Critical Thinker | Evaluating information and questioning why. More independent as a learner, trying to give their own explanations.<br><br>**Asking: Am I thinking about this correctly?** | • Realize they need to connect facts with concepts<br>• Assess their knowledge of content through ability to do problems and justify answers<br>• Take ownership of what they do and don't know<br>• Assess their understanding through ability to explain it<br>• Realize how different models used have different strengths and evaluate when to use each | • Try to put what they read into their own words<br>• Intend to use ideas from text to make their own connections between ideas.<br>• Read text or solutions to connect concepts to explain solution steps<br>• Reference alternative sources for confusing concepts<br>• Use the text as reference when clarifying concepts and working to develop their own understanding of how ideas link together | • Work problems on their own<br>• Ask for support after making a significant attempt on their own<br>• Work out past exam questions and then confirming how to solve it (solution steps) with the key or peers.<br>• Ask why the given solution works and what other types of questions could be solved with the same approach.<br>• Ask for help to understand the underlying process | • Evaluate others explanations to compare with their own understanding<br>• Work collaboratively with peers (dialog focused more on clarification of the concepts than the answer)<br>• Explain to others why or how things work and clarify with each other<br>• Compare answers to problems and discuss why the solution works<br>• Confirm why the given solution is correct based on concepts learned. |
| 2 | Procedural | Taking in the information and making small connections. Still relying on others or course materials for answers.<br><br>**Asking: How do you do this?** | • Realize there are connections they are not making with the material<br>• Assess their knowledge through whether they think they can solve the problems or through their ability to recognize content from topic headings or feelings of confidence<br>• Assess for procedural mistakes made when answering questions<br>• Concerned with points earned and grading more than content | • Rely on text to explain ideas to them<br>• Reading notes or text with the intent of trying to learn ideas<br>• Read text and trying to make some connections between the individual facts.<br>• Read text or solutions to memorize steps on how to solve given types of problems or find answers<br>• May be memorizing the connections between ideas. | • Try to work out problems<br>• Rely on external help<br>• Work out past exam questions while consulting with answer key.<br>• Ask procedural questions of how to answer specific questions.<br>• Consult answer key to confirm answers (assess for correct or incorrect answers only)<br>• Rely on others for help when they get stuck. | • Seek out others to form a study group<br>• Go to office hours, review sessions, or work with peers<br>• Not collaborative: either giving explanations or asking for others to explain but not clarifying with each other.<br>• Ask how to solve given problems<br>• Participate by listening to others or asking questions |
| 1 | Memorizer | Memorizing independent facts.<br><br>**Asking: What is the answer?** | • Not using metacognition<br>• Judging grades received on how much time spent studying with no connection to assessment of content knowledge | • Become familiar with topics from topic headings or boldface text<br>• Look over/skimming text/notes with no real intent or purpose<br>• Read text with the intent of memorizing facts or gaining vocabulary.<br>• Use text as a reference to find facts or answers | • Not working out problems on their own<br>• Look at past exam questions and solution keys to learn how to do the given problems<br>• Memorize use of an algorithm or formula | • Not working with others, or only asking peers for the answer to specific questions (not HOW to solve it, just the answer) |

**Description of Use of Resource Framework Levels**
Each of the levels identified in the Use of Resources Framework are described in detail below. Examples of behaviors students may exhibit when using each of the resource categories are outlined as well as more general behaviors they may demonstrate.

*Level 1*
A level 1 student is mainly asking the question "what is the answer?" They frequently describe learning chemistry as memorization of discrete facts, algorithms, and possibly a few models. They are not trying to connect these facts actively to any underlying theory or broader concepts. In taking a passive approach to learning, they look to external sources for answers and explanations rather than to gain deeper understanding. Their primary intent in learning chemistry is to find the answer rather than to understand how to generate the answer. When using text-based resources they are characterized by skimming the material to survey the topic headings and boldface terms. These students do not have a clear intent or objective towards reading text, they simply scan or read it hoping to gain knowledge or familiarity of the subject. They do not try and solve problems on their own, instead they focus on studying solutions already worked out. They do not work with other students except to ask for the answer to specific questions. These students assess their progress in the course not through content knowledge, but simply time on task or perceived effort.

**Figure 13: Level 1 Sample Responses**

| **Metacognition** | **How this looks for different types of resources……** | | |
|---|---|---|---|
| | **Text Based Resources (textbook / internet /lecture slides/webcasts)** | **Solving Problems (OWL / Past Exams/Textbook Problems)** | **Seeking out Others (office hours / studying with peers/ SLC)** |
| • I know there are a lot of resources out there but because there is so much work I constantly fall behind easily. ….. There is so much information, it is so overwhelming, I don't even have time to stop and comprehend the material<br>• it (exam score received) was extremely low, and I thought that I studied very hard and I understood the concepts well enough and then I saw the grade I was like (surprised look)<br>• I don't know why I got that score, I was really confused | • And then I made note cards, I went through all the lecture slides and made note cards on that.<br>• I looked over all the slides<br>• I read through the chapters<br>• I kind of just looked back over the lecture slides and little notes I had taken on it, and skimmed through the book and looked at each big header or section and said ok I know how to do a problem if its based off that | • even though I wanted to take practice midterms I didn't really get the chance or the time so I just briefly went over each question and answer<br>• It was not helpful since none of those questions were on the exam<br>• I kind of just looked at them and then came up with the answer in my head and looked at the answer and was like oh ok that's how you do it | • I have not gone to office hours<br>• I did not work with anyone else. I find I do better working alone<br>• I would sometimes ask my roommate for help with OWL |

*Level 2*

A level 2 student may frequently view learning chemistry as involving memorization of facts, yet unlike students categorized in level 1, the level 2 students also look to learn how these facts connect. While they may still not be clear on how to study effectively, they are realizing that there are connections between ideas that they do not understand. This is many times displayed through quotes referring to their level of metacognition such as "I know I am behind, I know there are things I don't understand....I just have to figure that out." Similar to a level 1 student, they may present frustration on the topic of how to study yet they also admit to their lack of knowledge or mastery of the material. For level 2 students, poor performance on exams is no longer blamed on a lack of time. They are beginning to admit to themselves and others that they have gaps in their knowledge due to a lack of understanding. These students are beginning to realize that they may need to find new strategies to understand the content better and improve performance in the course.

A level 2 student relies on external sources to explain or connect the ideas presented, as he/she is not able to make these connections on his/her own. Similar to the level 1 student, a level 2 student looks to the “expert” for information. The level 2 student takes a less passive approach to learning and assesses his/her performance for procedural mistakes and general confidence in the subject matter. Looking to the “expert,” level 2 students tend to rely on text-based resources, instructors, or peers, to explain ideas to them, rather than generating explanations themselves. When using text-based resources their intent is to learn the concepts and connections between ideas. When solving problems they look to external sources such as text or peers for procedural steps to memorize. When working with others they participate by asking questions and giving answers, but they do not evaluate the exchanged information. On one hand, a level 2 student may be described as a student who has highlighted most of the textbook in a variety of colors, but never evaluated what information to attend to. On the other hand, he/she may have attended to everything, and memorized all the information presented, including the links between ideas. While these level 2 students have taken the extra step of trying to understand the ideas presented beyond the surface level "skimming" of a level 1 student, they are still accepting all the ideas presented as pure fact and not evaluating the information for themselves or putting it in their own words.

**Figure14: Level 2 Sample Responses**

| Metacognition | How this looks for different types of resources…… | | |
|---|---|---|---|
| | **Text Based Resources (textbook / internet /lecture slides/webcasts)** | **Solving Problems (OWL / Past Exams/Textbook Problems)** | **Seeking out Others (office hours / studying with peers/ SLC)** |
| • Right now where I am I can't think of anything to do, I have done all my homework, I have done the preclass, I have done my labs, like I've done everything and then I'm like how do I study? But I know I am behind, I know there are things I don't understand....I just have to figure that out<br>• I knew I needed to try and think more for like how I would for the test, putting things together and making conclusions but I didn't know how to go about that | • I looked over the lecture slides and I jotted down the main points of each slide<br>• The book expanded on the topics a little more than the lecture notes did 'cause a lot of the stuff prof teaches isn't in, well there is more in the text than the lecture notes so it is an expansion<br>• The first time I read the textbook I just looked for the main points. Then the second time I read it was filling in the blanks to make a better overall picture. …… to understand how the basics would be applied and other information that would determine how to use the points | • I did the past reviews, well exams. I crossed out the ones I felt confident in and I worked on the ones that I didn't<br>• I would take it (past exam) and then look at the key and then the next page, take, look at the key, and so on and so forth….<br>• I study in groups now so we kind of just do the practice test together and then we talk about it | • I have gone to office hours<br>• I went to a review session<br>• I would only go to office hours if I knew exactly what I wanted answered because then I could work with that instead of sitting through other peoples questions |

*Level 3*

A level 3 student begins to view learning chemistry in a more independent fashion. He/she is actively evaluating and critiquing the accuracy of information presented to him/her. He/she takes the information presented from external sources and puts it in his/her own words. Taking this step of evaluating the information and asking “am I thinking about this correctly?” is a critical step that distinguishes a level 3 student from a level 2 student. Using text-based resources as a reference to clarify his/her ideas and develop his/her own understanding, a level 3 student may often seek out multiple resources on a topic. His/her intention is not to rely on the text as the authority, but rather to translate what he/she is reading into his/her own words. When working with others, a level 3 student will collaborate to elicit ideas from one another and strengthen understanding through explanation and evaluation of each other's ideas. These students are more independent and would work out problems on their own. Often, only after struggling with the problem and exhausting their own resources will level 3 students consult with other students or course staff. They assess their level of understanding through their ability to solve problems and explain ideas. Level 3 students are those who may present their questions along with how they are currently thinking about the idea when seeking help from others. They are not simply asking what the answer is or how to solve a problem. They are looking to confirm if they have understood the process and are thinking about it correctly. These students are not memorizing more than the basic information; instead they focus on learning the theories to explain various phenomena. Many times these students may continue to ask questions even if they already understood how to get a solution because their intent is to understand not only the solution but the reasoning behind it as well.

**Figure 15: Level 3 Sample Responses**

| **Metacognition** | **How this looks for different types of resources……** | | |
|---|---|---|---|
| | **Text Based Resources (textbook / internet /lecture slides/webcasts)** | **Solving Problems (OWL / Past Exams/Textbook Problems)** | **Seeking out Others (office hours / studying with peers/ SLC)** |
| • In other units we had one central concept or one central image and once you got the right way of thinking about it everything else was intuitive. Without that central image here, it wasn't here or I didn't get it, I had a lot more trouble remembering things because I had no overall structure to hang them on<br>• it was more a struggle for me to apply my knowledge because it seems like different rules can apply during different situations for chemistry and I had to figure out which one applies best in this situation<br>• chemistry here is about how you think not about what you know, as opposed to AP chem its more about what you know like the more concepts you memorize the better you are but now its like the more effective you think the better you are here | • I am rewriting some of my notes and kind of going through the entire semester and while rewriting them trying to connect them to what we just learned because before you learned a little bit, a little more and had to connect it backwards, and a little more and tried to connect it backwards. Now I am going back and trying to connect it to all the stuff I tried to learn and see if they explain something that I wasn't able to before<br>• this class is a lot faster (than high school chemistry). A lot of details you need to look up on your own. Its not like they are going to stop every time you have a question, you have to go through the book or to your GSI and ask them<br>• I have to read it and then reword it in language that I understand | • First I take a practice midterm online and then I see which topics I'm having trouble with, I look those up, like I look through all the lectures to find those and then I look it up in the book, then I take the second midterm, like the second practice midterm, and then once I have taken that like I just skim over all the lecture slides again and then I take the midterm from this year again and see how I do<br>• answered on my own, compared my answers with the key, saw what I got wrong and then from there I just took the questions I got wrong, looked at why I got it wrong, different approaches to it, and then general approaches to those types of questions.. .... | • it helps me reaffirm what I am thinking. First I will try looking through it and then I will talk with my friend and then we resolve any issues or differences between our answers<br>• when I read the book I think oh I know this but then when I talk with other people and they show me different ways of doing it or different ways of viewing it to solve it I am thinking ok so I know just part of this and its better if I communicate with others people so if I know something I can tell them or if they know something they can tell me<br>• talking over things with other people and both getting help from other people and helping other people helped me reaffirm things myself. I realize if I can't explain it to someone else I am not understanding it myself |

*Level 4*

Level 4 students share many of the level 3 student characteristics but extend their approach to ask "how does this apply to what I see in the world?" The main difference between a level 3 and a level 4 student is this focus on real world application of scientific concepts. These students are looking actively to explain the world around them and how the content learned in class relates to the larger picture. Level 4 students may be less focused on simply meeting course requirements and learning to achieve high grades. Instead, they are more concerned with the big picture and learning to satisfy genuine curiosity. Level 4 students use the world around them as a resource to confirm their ideas and assess their understanding.

**Figure16: Level 4 Sample Responses**

| **Metacognition** | **How this looks for different types of resources……** | | |
|---|---|---|---|
| | **Text Based Resources (textbook / internet /lecture slides/webcasts)** | **Solving Problems (OWL / Past Exams/Textbook Problems)** | **Seeking out Others (office hours / studying with peers/ SLC)** |
| • I check for understanding of the key concepts. I look around and think can I explain what's happening here with what I just learned. | • I read the book to get the concepts and then I started thinking about what types of things in our world related to those concepts and how to process that and started from there and really looking at one concept from multiple perspectives. I find that chemistry has a lot of that, I keep on finding there are different explanations for things and they all kind of piece together in the end | • I look around and think can I explain what's happening here with what I just learned. The other is I do lots of problems, various types of problems from the book and other sources. I think what's important about doing problems from different sources is they test for your ability to apply concepts to situation you have never seen before | • We would each pick something like putting sugar in our coffee and then try and teach to each other why it happened. Then as one of us was explaining our topic others would ask questions and point out things that did not seem to make sense. We would all discuss it and once the issue was resolved the one "teaching" would continue until they were done with that topic. We would each take turns "teaching". |

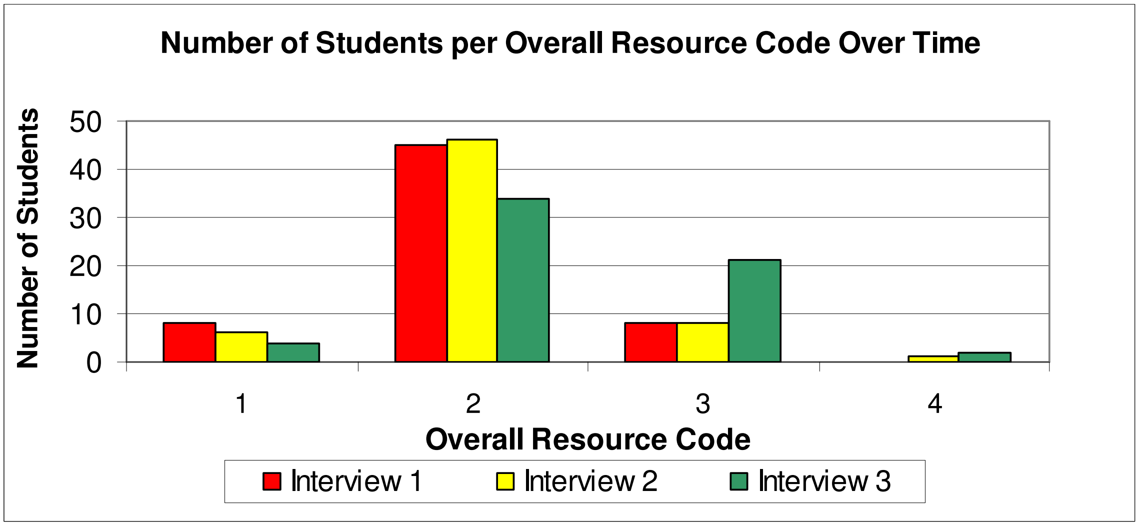
## Evaluation of Use of Resource Behavior Categorizations

Correlations of student exam scores with overall resource code at each interview time point are analyzed in this section. This analysis demonstrates the ability of student's overall resource code to distinguish exam performance. This section also includes data on student's overall resource use trajectories over the semester to evaluate if they were primarily moving up, staying the same, or moving down in level.

*Distribution of Students into Overall Resource Code Assignment*

Figure 17 below shows the trends in numbers of students assigned to each resource code category. Table 17 includes counts of students in each category, over time, as well. Over time, the number of students categorized as a level 1 for their use of resources decreased by 50%. Along with this, the number of students categorized as a level 3 for their use of resources almost tripled.

**Figure 17: Graph of student distributions into overall resource code categories**




*Effect of Overall Resource Code on Exam Performance*
Student use of resources was found to have a significant impact on students mean exam performance for most exams in the course. This was determined using multiple methods to compare overall resource use code to exam performance. Exam percentiles were used for comparison since exams in the course covered different chemistry concepts. Converting student individual exam scores into percentile scores was done to account for differences in exam difficulty. The general strategies used, or behavior students exhibited towards their use of resources, is reflected by the overall resource code they were assigned. The findings detailed below (Tables 17, 18 & 19) demonstrate that the behavior students employ towards their use of resources in the course impacts how they perform on exams. Students who use behaviors characteristic of levels 3 or 4, on average, perform above the mean in the class. This demonstrates how using less passive, more independent behaviors towards use of resources has a positive impact on course performance. This also suggests that if a student were to change his/her behaviors to mirror a higher level within the use of resources framework, his/her exam performance might increase.

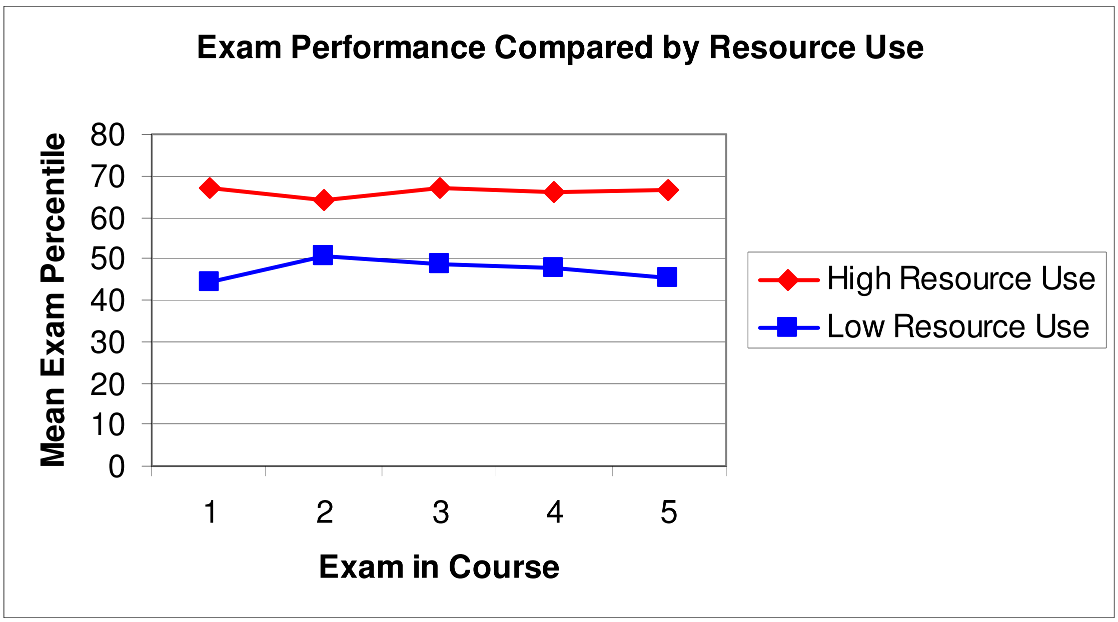
- *Evaluation of mean exam performance by high and low resource use*

Students were split into high and low resource use categories to evaluate the difference in mean exam scores over the semester for these two groups. Students were considered to have a high resource use if their mean resource use code was above 2 for the semester. Students categorized to have a low use of resources had a mean resource use code below or equal to 2 for the semester. When divided this way, 37 students were assigned to the low resource use group, while 24 students were categorized as high resource use. A significant difference was found between mean exam scores for these two groups of students for all exams, except exam 2 ($p<0.05$). Table 17 and Figure 18 show the mean exam scores for each group.

**Table 17: Mean exam performance for high and low resource use groups.**
p-value indicates significance determined by t-test comparing mean performance by resource use group.

| | Mean Exam Score | | |
|---|---|---|---|
| Exam | High Resource Use | Low Resource Use | p-value |
| 1 | 66.75 | 44.3 | 0.0028 |
| 2 | 63.975 | 50.673 | 0.0894 |
| 3 | 67.05 | 48.67 | 0.0162 |
| 4 | 66.00417 | 47.88 | 0.006 |
| Final | 66.475 | 45.43784 | 0.0035 |

**Figure 18: Graph of mean exam performance for high and low resource use groups**



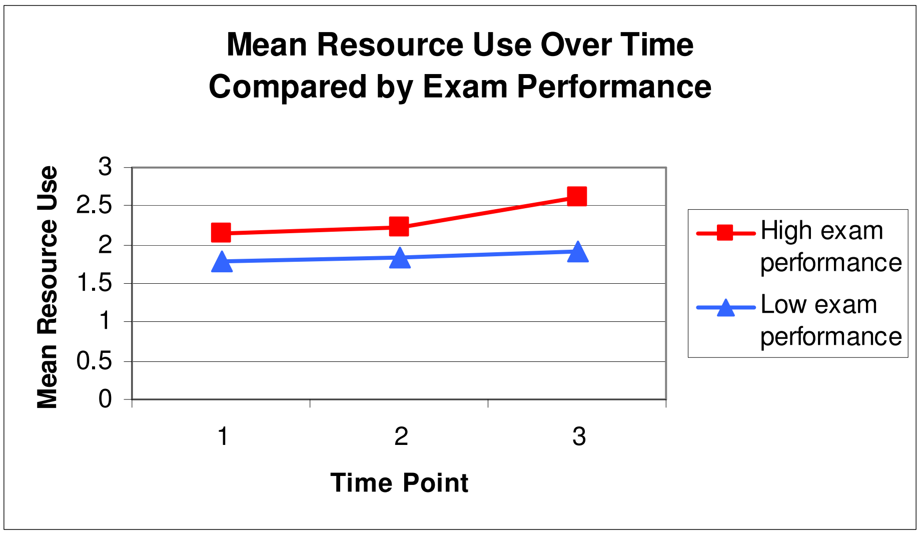

- *Evaluation of mean use of resource code by high and low exam performance*

Students were split into high and low exam performance categories to evaluate the difference in mean use of resources over the semester for these two groups. Students were considered to have high exam performance if their mean exam performance was above the 50th percentile. Students categorized to have low exam performance had a mean exam performance below or at the 50th percentile for the semester. When divided this way, 24 students were categorized as low exam performing, while 37 students were categorized as high exam performing. A significant difference was found between mean resource use for these two groups of students at each time-point ($p<0.05$). Students using resources on average above a level 2 demonstrate higher exam scores than those using resources on average at or below a level 2. Table 18 and Figure 19 show the mean resource use codes for each exam performance group.

**Table 18: Mean resource use for high and low exam performance groups.**

| | Mean Resource Use | | |
|---|---|---|---|
| Time Point | High Exam Performance | Low Exam Performance | p-value |
| 1 | 2.14 | 1.79 | 0.01 |
| 2 | 2.22 | 1.83 | 0.0062 |
| 3 | 2.62 | 1.92 | <0.001 |

**Figure 19: Graph of mean resource use for high and low exam performance groups**




- *Evaluation of mean exam performance by each use of resource category*

When considering each use of resource category individually, a significant difference was found in the mean exam performance for 3 of the 4 exams considered (exams 1, 4, and the final exam). This significance was determined from ANOVA test results having p-values below 0.05 ($p<0.05$, see Table 17 for details). Exam 2 demonstrates a marginally significant effect from student use of resources on exam performance ($F(3, 57) = 2.57$, $p=0.0631$). Exam 3 in the course was not included since no interviews were collected after this exam. Figure 20 and Table 19 below illustrate how the mean percentile for students in each overall resource group compares across exams.

**Figure 20: Graphs of mean percentiles by resource code assigned separated by exam.** Exam 5 was the final exam in the course. The third exam in the course was not included since no interviews were collected after this exam.

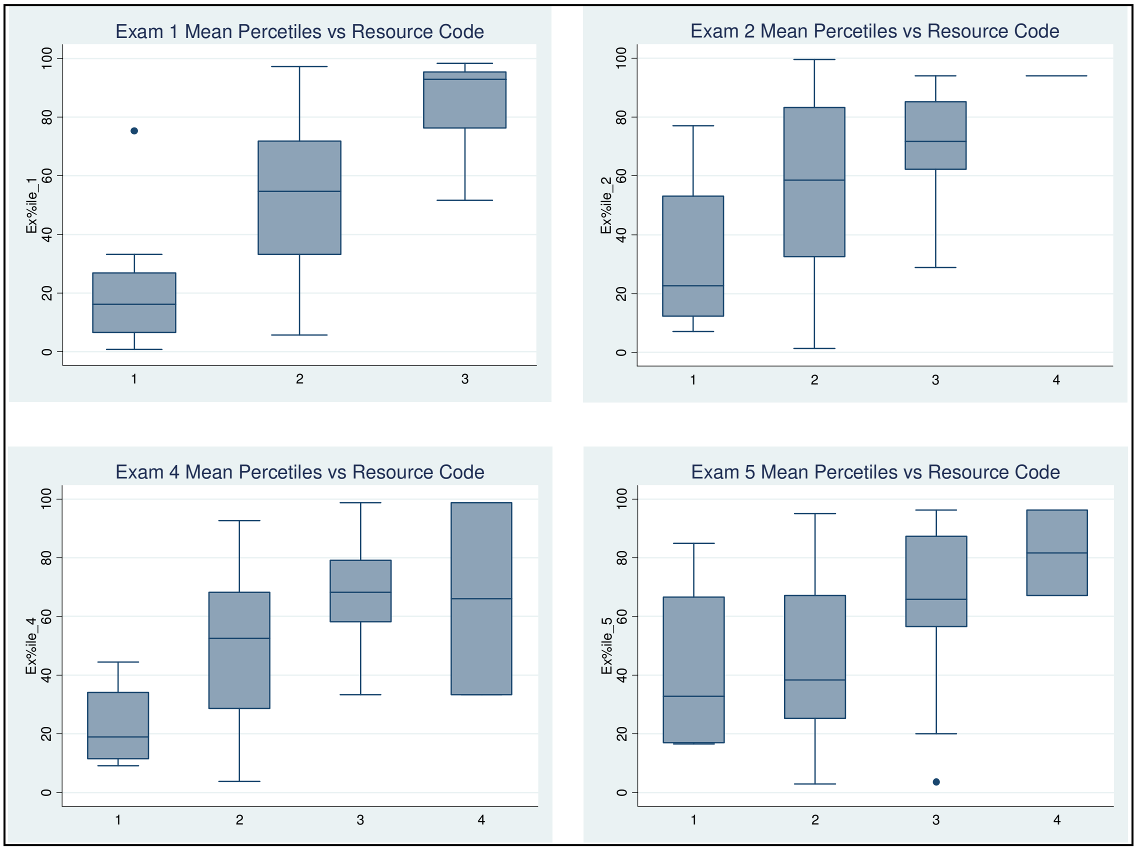



**Table 19: Summary of Exam Percentile Means by Overall Resource Code Category**

| | # of Students | Mean Percentile | St Dev |
|---|---|---|---|
| Exam 1 [F(2, 58) = 12.76, p<0.001] | | | |
| Resource Code 1 | 8 | 21.96 | 23.8 |
| Resource Code 2 | 45 | 53.04 | 26.11 |
| Resource Code 3 | 8 | 84.84 | 17.22 |
| Resource Code 4 | 0 | - | - |
| Exam 2 [F(3, 57) = 2.57, p=0.0631] | | | |
| Resource Code 1 | 6 | 32.5 | 27.57 |
| Resource Code 2 | 46 | 55.67 | 29.95 |
| Resource Code 3 | 8 | 70.14 | 20.56 |
| Resource Code 4 | 1 | 94 | - |
| Exam 4 [F(3, 57) = 4.79, p=0.0048] | | | |
| Resource Code 1 | 4 | 22.85 | 15.63 |
| Resource Code 2 | 34 | 50.88 | 25.95 |
| Resource Code 3 | 21 | 66.9 | 17.88 |
| Resource Code 4 | 2 | 66.05 | 46.17 |
| Final Exam [F(3, 57) = 3.82, p=0.0146] | | | |
| Resource Code 1 | 4 | 41.73 | 32.31 |
| Resource Code 2 | 34 | 45.54 | 27.24 |
| Resource Code 3 | 21 | 66.67 | 23.91 |
| Resource Code 4 | 2 | 81.7 | 20.65 |

*Effect of Individual Resource Codes on Exam Performance*
Since not every student received a code for each resource at each time-point, researchers decided to focus primarily on the Overall Resource Code assigned to each student for comparison. However, a short overview comparing student's exam performance by their use of resource, considering each individual type of resource separately, is provided in Table 20 below. Again, mean exam percentiles were used for comparison of each group since exams in the course covered different chemistry concepts and this helped to account for differences in exam difficulty. Since not every student was coded for each type of resource, at each time-point, the data in Table 20 represent just those students who were coded for these resources at the given time-point. The total number of students coded for each subcategory is represented by the N reported for the F statistic, F(x, N).

**Table 20: Summary of differences found between students compared for approach within resource subcategories**

| **Resource Subcategory** | **F statistic** | **p-value** |
|---|---|---|
| **Metacognition** | | |
| Exam 1 | $F(2, 58) = 6.13$ | 0.0038 |
| Exam 2 | $F(3, 57) = 2.06$ | 0.1152 |
| Exam 4 | $F(3, 57) = 6.18$ | 0.0010 |
| Final Exam | $F(3, 57) = 7.30$ | 0.0003 |
| **Text** | | |
| Exam 1 | $F(2, 56) = 7.70$ | 0.0011 |
| Exam 2 | $F(3, 46) = 0.88$ | 0.4568 |
| Exam 4 | $F(3, 34) = 5.43$ | 0.0037 |
| Final Exam | $F(3, 34) = 1.93$ | 0.1438 |
| **Problem Solving** | | |
| Exam 1 | $F(2, 58) = 5.22$ | 0.0082 |
| Exam 2 | $F(2, 48) = 0.88$ | 0.4202 |
| Exam 4 | $F(3, 19) = 1.08$ | 0.3810 |
| Final Exam | $F(3, 19) = 1.61$ | 0.2201 |
| **Peers** | | |
| Exam 1 | $F(2, 57) = 2.03$ | 0.1408 |
| Exam 2 | $F(2, 52) = 2.19$ | 0.1220 |
| Exam 4 | $F(2, 41) = 0.30$ | 0.7449 |
| Final Exam | $F(2, 41) = 2.31$ | 0.1125 |

It is evident by comparing the p-values reported from the ANOVA results that there are some significant performance differences at the 5% level found by comparing categories within student use of individual types of resources. A p-value below 0.05 indicates that there is a significant difference between average exam scores of students at the corresponding occasion divided into use of resource levels for the given subcategory. While performance between students in different use of resource groups may be distinguishable and significant on some exams for some resource subcategories, this does not hold true across all exams. Metacognition, for example, does not show a significant difference between mean percentile scores on exam 2 for different levels. Text levels are only significant in distinguishing mean percentiles between groups on 2 of the 4 exams (exam 1 and 4). Problem solving only demonstrates a significant difference in mean percentile between groups on exam 1, and does not show any significant difference between groups for mean percentile. These findings suggest that student use of one type of resource, taken individually, may not be a reliable indicator of performance.

Overall, these findings show no significant differences in mean percentile between groups across exams for any one type of resource taken on its own. However, when taken together, the students overall resource code differentiates performance between groups more effectively. Depending on their personal learning style or comfort level with different types of resources, students may use one resource type more or less than another. The resources they use less frequently may correspond to use of resource behaviors that are categorized at a lower level than resources they use more frequently. This may explain why the overall resource use coding is more effective in distinguishing student performance. The weighted averaging of resource use by resource type according to individual student use, allows the resources they use most often to have a larger influence on overall resource code. This results in a more meaningful student picture from the overall resource code. While how students use an individual type of resource, evaluated independently, may not determine their performance, their overall approach to the use of resources in the course, shows a significant effect on their performance.

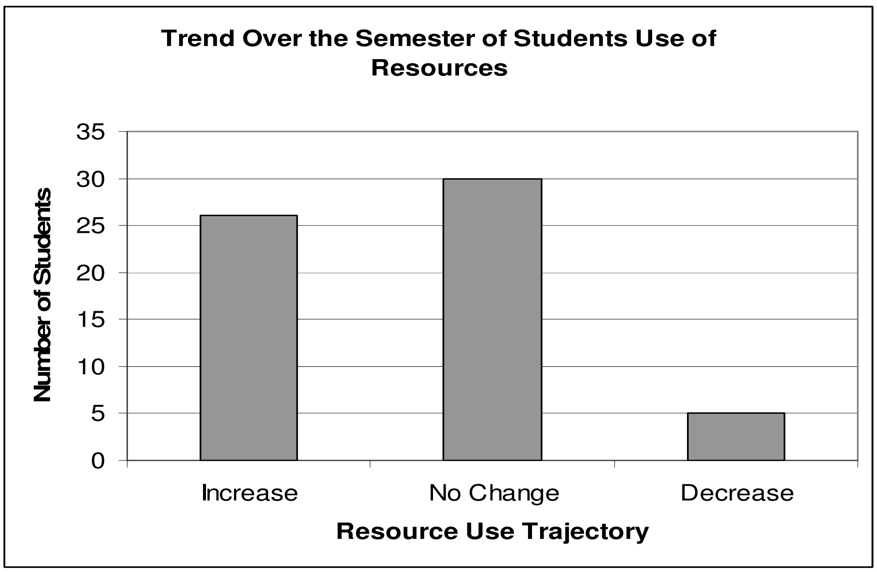
*Overall Resource Code Trajectories Over the Semester*

Students were grouped by their starting and ending overall resource codes over the semester to evaluate behavior trajectories for the course. It is evident from Table 21 and Figure 21 below, 43% (26 out of 61) of the students moved to a higher overall resource code while only 8% (5 out of 61) moved to an overall resource code that is lower than where they started. This increase of students especially from codes 1 and 2 to codes 2 and 3, respectively, is promising. This trend demonstrates the possible impact of the course on student studying strategies. The large number of students using course resources at a higher level over time, compared with the small number of students dropping to a lower level, implies a possibility that students are developing more effective approaches to studying independently. While this study does not go into the details behind this, anecdotal evidence from student interviews suggests this may be influenced in part by the exam style in the course. Multiple students mention the exam style pushing them to need to know the material at a deeper level and develop the ability to apply things they are learning in new situations during the exam. The exam style is cited repeatedly during interviews as motivating them to change their approach to learning when they study for this course.

**Table 21: Distribution of students into use of resource trajectories.**
Numbers indicate students demonstrating each overall resource code trajectory over the time period from occasion 1 (beginning of the semester) to occasion 3 (end of the semester).

| Resource Code Increased | | No Resource Code Change | | Resource Code Decreased | |
|---|---|---|---|---|---|
| Code Trajectory | # of Students | Code Trajectory | # of Students | Code Trajectory | # of Students |
| 1 to 2 | 8 | | | | |
| 2 to 3 | 16 | 2 to 2 | 25 | 2 to 1 | 4 |
| 3 to 4 | 2 | 3 to 3 | 5 | 3 to 2 | 1 |

**Figure 21: Graph of number of students per overall resource code trajectory.**
Overall resource code trajectory determined by student use of resources at the start and end of semester.




While it is difficult to determine the effect of these trajectories, since students may have made changes to their study habits at different points in the semester, and we only considered their use at the beginning and end of the semester, students who increased their resource code, on average, increased their exam score (M=49.47, SD=31.95 (exam 1); M=57.05, SD=30.10 (Final exam). This trend supports the idea that in order for a student to improve his or her performance in the course, he or she needs to change his or her approach to use of resources, and his or her studying strategies. The group of students who showed a significant change in their performance were students who moved from level 1 to level 2 in their use of resources [M = 21.96, SD = 23.8 (exam 1); M = 39.5, SD = 26.82 (exam 4), $t(8) = 2.96$, $p = 0.02$, d= 1.04]. Students who moved from level 2 to level 3 did not show an increase in mean percentile between exam 1 and exam 4, yet this increase was not statistically significant at the 5% level [M = 57.75, SD = 26.48 (exam 1); M = 66.2, SD = 17.77 (exam 4), $t(16) = 1.44$, $p = 0.17$, d= 0.36]. This change may be more difficult for students since they have to do more than move away from memorization of facts. To move from a level 2 to a level 3, a student must make a leap from using explanations given from text or other sources, to translating these explanations into their own words to explain connections between concepts. Students also must begin to rely on themselves as a source of authority to distinguish between correct and incorrect ideas presented. Students may require time to practice this evaluation of ideas presented before they become effective at distinguishing robustness of ideas. While students may report using strategies characteristic of level 3, it may take more time for them to become effective in using these strategies. Taking into account these possibilities, the transformation between level 2 to level 3 may require more time before the student is effective with their level 3 strategies. This would also result in a longer lag time before exam scores reflect their new approach to resource use.

**Discussion**

What study strategies do students demonstrate when using resources for the course and which behaviors prove most successful in developing scientific thinking? To answer this question, this study developed the Use of Resources Framework for Chemistry. The framework describes strategies students employ when studying outside the classroom which extant research does not address. This framework provides a venue to explore how students evaluate ideas presented in a chemistry course, along with ideas from prior experiences, and ideas they learn independently, to form links between related ideas and generate their own understanding of scientific phenomena. Finally, the framework is useful in linking use of resources and exam performance.

*Comparison of Resource Use Levels*

This framework addresses the issue of defining what strategies students demonstrate in their use of resources for the course. Students in levels 1 and 2 are acting as passive learners relying on external sources for understanding. In contrast, students in levels 3 and 4 do not act passively and take ownership of their own learning. Where students place the authority of knowledge is critical. Levels 1 and 2 students place the authority of knowledge externally while levels 3 and 4 students place authority within themselves to evaluate given information and take ownership of their learning. They develop an understanding of the concepts in their own words. During the Use of Resources Framework development, researchers debated whether levels 2 and 3 should be combined into one category. Students in both of these levels look to make connections between the ideas they are still learning; where they ultimately place the authority of knowledge separates them. This change from seeing outside sources as the "authority" to evaluating information by themselves motivated the decision to separate level 2 and level 3.

Many of the behaviors characterized as level 3 or level 4 shared similarities with effective curricular strategies reviewed. For example, student’s use of self explanation (Teichert & Stacy, 2002) shares this common idea of students translating ideas into their own words. Level 3 and level 4 behaviors include elements from the four meta-principles outlined in the knowledge integration framework for instruction (Linn et al., 2004) extended for use outside the classroom. To make science accessible, level 3 and level 4 students begin to deviate from the given text and apply the ideas they are learning to explain familiar phenomena. A level 4 student asks the question "How does this apply to what I see in the world?" To make thinking visible, a level 2 student realizes there are connections they are not making with the material. This awareness demonstrates how they are starting to make their thinking visible to themselves. Level 3 and level 4 students take this a step further and evaluate their ideas independently as well as through interactions with peers. This transition to evaluating ideas between peers is also evident in how level 3 and level 4 students are learning from others in a less passive and more effective way. By not just relying on peers for answers, these students are using peer interactions to generate their own understanding through connections between ideas. Students increased use of metacognition at higher levels demonstrates a promotion of autonomy.

These links to the principles in the knowledge integration framework, and elements of the modified curriculum used in this course, suggest these curricular elements may extend to learning outside of the classroom. Students characterized at a higher use of resource level appear to incorporate more of these elements. Given this, students who employ more behaviors incorporating these principles may have more success in developing scientific thinking when learning outside of the classroom.

*Effectiveness of Resource Use Behaviors*
Multiple analyses demonstrated that students using behaviors characteristic of higher levels, on average, performed better than students using lower level behaviors. Based on ANOVA results, a significant difference was found in mean exam performance for 3 of the 4 exams considered (exams 1, 4, and the final exam; see Table 19). This ability to distinguish exam performance by resource use highlights the importance of use of resources.

In summary, students who place authority within themselves to evaluate information, translate information into their own words, and make connections between ideas to form their understanding tend to perform higher than students who place authority on external sources and who do not evaluate the information given.

*Possible Effect of the Modified Curriculum*
Modifications made to the course curriculum may have encouraged students to use behaviors characteristic of higher levels. This is supported by the finding that a large proportion of the students evolved to use course resources at a higher level over the semester (43%) compared with the small number of students dropping to a lower level (8%). Inclusion of principles from the Knowledge Integration Framework for Instruction (Linn et al., 2004) may have modeled effective behaviors which could be translated for use when studying outside the classroom. Continual reference to familiar context throughout each curricular unit may have cued students to link these ideas with everyday ideas. Fostering peer interaction and evaluation of ideas in the course may have modeled ways to make students' own thinking visible to others as well as to encourage them to continue peer interactions outside the classroom. Exam items asking students to apply the ideas from the course in novel situations may also have an impact. Multiple students mention the exam style pushing them to need to know the material at a deeper level and develop the ability to apply things they are learning in new situations during the exam. This is cited repeatedly during interviews as motivating them to change their approach to learning when they study for this course. The modified curriculum may have influenced

students by modeling effective strategies for learning along with an exam style that encouraged students to apply ideas in novel situations.

**Study Limitation**

While this analysis demonstrates associations between student use of resources and exam performance, this does not take into account other characteristics that may be of importance. Students who are more prepared, engaged, or have more available resources due to a higher SES or other factors, may be both more resourceful as well as better equipped to use these resources from the start. Some of these confounding effects are explored in Chapter 7 when evaluating the influence of student's beliefs and perceptions on use of resources.

# Chapter 7: Relationship Between Student Beliefs, Perceptions, Behavior, and Course Performance

## Introduction

This chapter explores the question of what influences student behavior towards use of resources and how student behavior towards use of resources affects course performance. This chapter answers the third research question "How do beliefs and perceptions impact student behavior towards use of resources and student course performance?" In this study, use of resources refers to student behavior towards use of resources. This chapter's logic models and analysis extend the current literature by investigating the possible mediating role of use of resources. The ensuing analysis determines whether use of resources acts as a predictor alongside these beliefs and perceptions, or as a mediator of the effects of student beliefs and perceptions on course performance. Investigating the mediating role of use of resources can help explain the direct effects of student beliefs and perceptions on course performance.

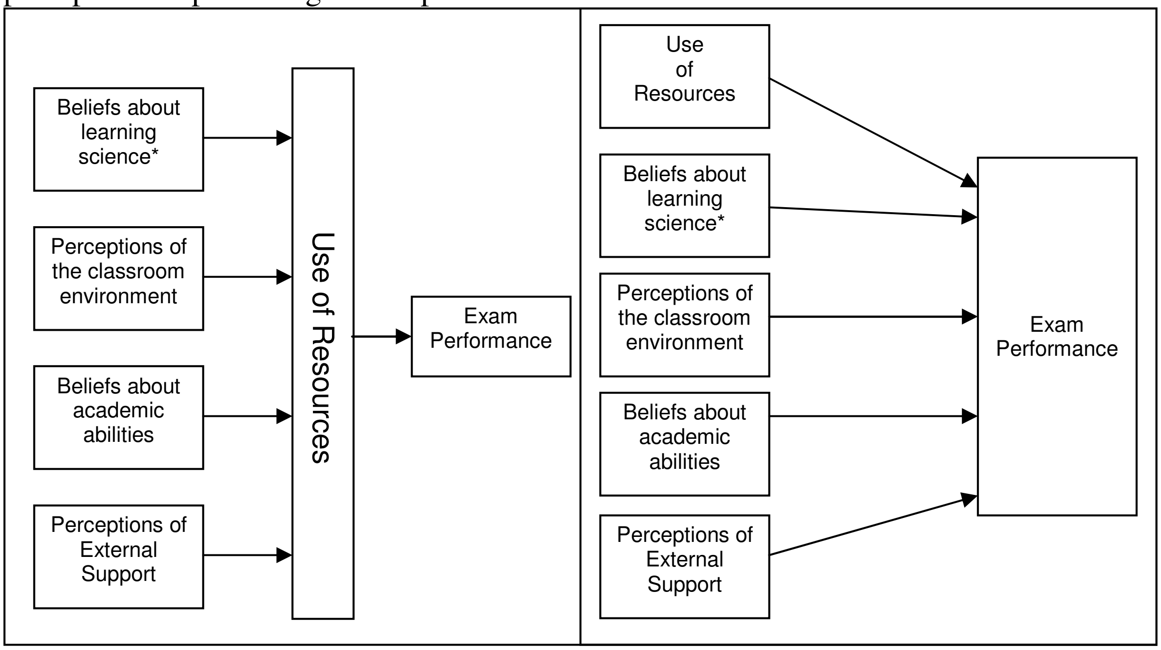
## Rationale

The analysis in this chapter includes a measure of student use of resources determined from individual interviews. Including a behavior measure expands previous findings that explore the direct effects of student beliefs and perceptions on course performance (see Chapter 5). The logic models used for analysis and the background literature motivating the proposed logic models are outlined in the following section.

### *Logic Models*

Building on previous literature, two logic models are proposed for evaluation. The logic models are presented in Figure 22. Logic model 1 evaluates use of resources as a mediator, and Logic model 2 evaluates the direct effects of use of resources on course performance. Logic model 1 tests the hypothesis that student use of resources is influenced by student beliefs and perceptions. If the mediating effect is found to be significant, use of resources can help explain the direct effects of student beliefs and perceptions on course performance. Logic model 2 tests the hypothesis that student use of resources has a direct effect on course performance and acts as a predictor alongside student beliefs and perceptions. If the mediating effects proposed in Logic model 1 are determined not to be significant, then Logic model 2 is used to determine direct effects on course performance.

**Figure 22: Logic models proposed for evaluation.** Logic model 1, proposing use of resources as a mediator, is shown on the left. Logic model 2, proposing direct effects of use of resources on course performance, is shown on the right. The logic models are used to define the role of use of resources when included with other student beliefs and perceptions in predicting course performance.




*The final analysis excluded beliefs about learning science. While it was considered in the creation of the logic models, it was dropped in the final analysis since there were concerns that the items used to create this variable did not capture the intended belief. See Chapter 4 for more details on these issues.

*Use of Resources*

Use of resources in this study refers to the behavior a student exhibits when using available course resources to study. Chapter 6 describes the Use of Resources Framework which outlines four levels to describe student use of resources. Higher level use of resources is characterized in levels 3 and 4. Students characterized by levels 3 and 4 place authority within themselves to evaluate information, translate information into their own words, and make connections between ideas to form their understanding. Students characterized by levels 1 and 2 use of resources place authority on external sources and do not evaluate the information given. A summary of these levels are presented in Figure 23. Complete details of the use of resource levels may be found in Chapter 6.

*Beliefs About Learning Science*

Many studies have found evidence to support the idea that a more dynamic view of science leads to a deeper understanding of the content (Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Rosenberg, Hammer, & Phelan, 2006; Songer & Linn, 1991; Stathopoulous & Vosniadou, 2007). This deeper understanding has been explained by the possibility that a dynamic belief may increase student understanding by increasing emphasis on conceptual understanding or by the student integrating ideas.

Building on the findings from previous studies, this study proposes that a more dynamic view of science will lead students to ask more questions about what they are learning, which, in turn, will result in students using course resources more effectively. Students use course materials more effectively when they take a more active role towards learning the material. A hypothesis of this study is that use of resources acts as a mediator between student beliefs about learning science and course performance since a more dynamic belief about learning science will influence students to use course resources at a higher level.

*Beliefs About Their Academic Abilities*

Acting as a measure of beliefs about their academic abilities, student self-concept has been found to demonstrate a positive effect on course performance or conceptual understanding (House, 1995; Nieswandt, 2007). Previous studies exploring beliefs about their academic abilities however do not consider the role of use of resources. This study proposes that an increased belief in their academic ability will result in a more effective use of resources.

Increasing beliefs in their academic ability allows students to approach resources they are using with more confidence. This confidence from an increased self-concept in chemistry may act to allow students increased authority to evaluate the information received, determine its accuracy, and translate information from multiple sources to create their own understanding. A hypothesis in this study is that use of resources acts as a mediator between beliefs about their academic abilities and course performance since increasing beliefs in their academic abilities will provide confidence needed for students to use course resources at a higher level.

*Perceptions of the Classroom Environment*

Perceptions of the classroom environment have been suggested to affect student course performance through different explanations (Ali, Rohindra, & Coll, 2008; McGlone & Aronson, 2006). The stereotype threat literature suggests that the explanation lies in students identification of themselves with a group believed to perform in a certain way (Steele & Aronson, 1995). It has been suggested that creating a more supportive learning community will create alternative and more positive identities with which students can associate (McGlone & Aronson, 2006). Other researchers have focused their explanation using student perception of the equity and involvement for the group with which students identify (Ali et al., 2008).

This study expands the literature by including use of resources to explain the link between perceptions of the classroom environment and course performance. The current study posits that when students do not perceive the course environment to be equitable towards them, they may take a more passive role in their use of course resources. Afraid to ask questions or seek out study partners, they may become more isolated and passive in their use of resources. A hypothesis in this study is that use of resources acts as a mediator between student perception of the classroom environment and course performance since an increased perception of the classroom environment will influence students to use course resources at a higher level.

*Perceptions of External Support*

At the university level, Roman, Cuestas, and Fenollar (2008) found students demonstrated a positive effect of family support on academic achievement, which was mediated by the students learning approach. Increased academic achievement was attributed to an increase in deep processing, effort, and self-esteem due to the influence of family support. Given these findings, the current study aims to provide further support for the mediating effect of student learning approach. Inclusion of use of resources attempts to replicate these findings on learning approach. Deep processing is believed to be characterized in the current model by more active behavior in use of resources, which results in increased performance. A hypothesis in this study is that use of resources acts as a mediator between student perceptions of external support and course performance since an increased perception of support will give students the confidence to use course resources at a higher level.

## Methods

Analysis was performed using measures collected from survey responses and interview data combined with student exam scores from the course. Student beliefs, perceptions, and demographic information were measured from responses on the Students Beliefs and Perceptions Survey. Chapter 4 provides details of the survey instrument. Issues with items attempting to measure student use of resources were found during the development of the Student Beliefs and Perceptions Survey. Items generated to measure student use of resources were not found to accurately discriminate between underlying behaviors towards various resources. Due to this inability to discriminate well between behaviors, these items were not considered robust enough for further use. To capture the necessary details to measure student use of resources, individual interviews were conducted instead. Measures for use of resources were then determined from interviews using codes based on the Use of Resources Framework for Chemistry. See Chapter 6 for full details of the interview collection, analysis, and framework development. By using these combined data, the relationship between student beliefs, perceptions, behavior, and course exam scores was explored.

The analysis proceeded by analyzing logic model 1. In the event that the mediating effects of student use of resources were nonexistent, logic model 2 would be analyzed. Analysis of logic model 1 required two steps. First, an ordinal logistic regression model was used to determine if any of the student beliefs or perceptions measures had a significant effect on student behavior toward use of resources. Second, an ordinary least squares regression model was used to then evaluate the effects of use of resources, and any belief or perception variables not found to influence use of resources, on exam scores.

The analysis was conducted for data collected at occasion 1. Occasion 1 corresponds to the week following the first exam in the course. Since not all students who participated in interviews responded to surveys 2 and 3 collected at later occasions, it was decided to conduct the analysis only at occasion 1 to maximize sample size. If necessary, logic model 2 will be analyzed using ordinary least squares regression.

**Participants**

Participants were students enrolled in the introductory chemistry course at a large public university. This course enrolls approximately 1300 students each Fall semester. This course is designed for non-chemistry majors who need to take chemistry as a pre-med or major requirement.

All students in the course were invited to participate in the study. Of the students who participated through survey responses during Fall 2009, a representative subset of 61 students participated in interviews. For the current analysis, measures were collected from those 61 students who responded to the initial survey and completed a series of three interviews over the semester. Table 22 compares the demographic make-up of the representative sub-set, used for analysis collected during Fall 2009, with the entire sample population.

**Table 22: Demographic information comparing the survey population from Fall 2009 with the sub-set selected for analysis.** Number of students (N), and percentage of sample population (%), self reporting to be included in each demographic category for each sample population. Each of the demographic categories was represented by dummy variables for analysis. Fall 2009 sample includes all students who responded to all 3 surveys, and represent the full sample. Analysis group includes all students selected for the current analysis. ($N_{2009}$=428; $N_{Analysis}$=61)

| **Variable** | **Category** | **Fall '09** | | **Analysis Group** | |
|---|---|---|---|---|---|
| | | **N** | **%** | **N** | **%** |
| **Major** | Life Science* | 225 | 52.6 | 27 | 44.3 |
| | Engineering | 94 | 22.0 | 14 | 23.0 |
| | Physical Science/Mathematics | 10 | 2.3 | 4 | 6.6 |
| | Humanities | 15 | 3.5 | 4 | 6.6 |
| | Undeclared | 62 | 14.5 | 8 | 13.1 |
| | Other | 22 | 5.1 | 4 | 6.6 |
| | | | | | |
| **SES** | Wealthy | 11 | 2.6 | 1 | 1.64 |
| | Upper-middle or professional middle | 165 | 38.6 | 30 | 49.2 |
| | Middle-class* | 157 | 36.7 | 21 | 34.4 |
| | Working-class | 43 | 10.0 | 5 | 8.2 |
| | Low-income or poor | 52 | 12.1 | 4 | 6.6 |
| | | | | | |
| **Ethnicity** | Chinese/Chinese-American | 142 | 33.2 | 16 | 26.2 |
| | East Indian/Pakistani | 27 | 6.3 | 4 | 6.6 |
| | Korean/Korean-American | 47 | 11.0 | 2 | 3.3 |
| | South East Asian | 17 | 4.0 | 3 | 4.9 |
| | Other Asian | 25 | 5.8 | 4 | 6.6 |
| | Mexican/Mexican-American/African-American/Black | 10 | 2.3 | 3 | 4.9 |
| | White* | 98 | 22.9 | 24 | 39.3 |
| | Mixed | 47 | 11.0 | 2 | 3.3 |
| | Other | 15 | 3.5 | 3 | 4.9 |
| | | | | | |
| **Gender** | Female* | 264 | 61.7 | 34 | 55.7 |
| | Male | 164 | 38.3 | 27 | 44.3 |
| | | | | | |
| **Total** | | **428** | | **61** | |

*used as reference category in regression and ordinal logistic analyses

**Variables Created**
Table 23 provides details on the type of variables created and the scales used. Subscales labeled Ability, Support, and EnvP were created based on previous factor analysis results (see Chapter 4 for complete details). Information on these subscales, and other variables created are given in more detail below.

**Table 23: Summary of the variables used for analysis, their type, and range**

| Variable | Used As | Type | Scale |
|---|---|---|---|
| Overall Resource Code | Response /Explanatory | Categorical | 1/2/3/4 |
| ExamPercentile | Response | Continuous | 0-100 |
| Ability | Explanatory | Continuous | 1-4 |
| Support | Explanatory | Continuous | 1-4 |
| EnvP | Explanatory | Dichotomous | 0/1 |
| 5 dummies for major | Explanatory | Dichotomous | 0/1 |
| 4 dummies for SES | Explanatory | Dichotomous | 0/1 |
| 8 dummies for ethnicity | Explanatory | Dichotomous | 0/1 |
| Female | Explanatory | Dichotomous | 0/1 |

**ExamPercentile** represents student exam score, standardized (percentile scores). This was collected from students first exam score for the course and focused on the "matter" unit in the course.

**Overall Resource Code** was assigned to each student based on the Use of Resources Framework levels. These were determined based on interview analysis. Levels coded for are described in Figure 23.

**Figure 23: Summary of Use of Resources Framework levels.** The complete framework included in Chapter 6 was used for coding student use of resources.

| Level (code) | Description |
|---|---|
| 4 Researcher | Taking in the information, questioning why this is true and how it helps to explain the world around them. **Asking: How does this apply to what I see in the world?** |
| 3 Critical Thinker | Evaluating information and questioning why. More independent as a learner, trying to give their own explanations. **Asking: Am I thinking about this correctly?** |
| 2 Procedural | Taking in the information and making small connections. Still relying on others or course materials for answers. **Asking: How do you do this?** |
| 1 Memorizer | Memorizing independent facts. **Asking: What is the answer?** |

**Ability** represents the variable created to capture student beliefs in their academic ability**.** The subscale labeled "Ability" was created by averaging student Likert scale responses to the items in Figure 24 (grouping determined from factor analysis results, see Chapter 4 for details). The responses were coded 1=strongly disagree, 2=somewhat disagree, 3=somewhat agree, 4=strongly agree. Reverse scale in Figure 24 indicates students responses were considered to be the reverse of the scale above when coding them. All Ability items have a factor loading of 0.46 or higher into their subscale (see Chapter 4). The Cronbach alpha reliability coefficient for the seven items used to create the variable Ability in the Fall 2009 survey was 0.83. Reliability was determined based on the factor loadings being above 0.30 and Cronbach alpha above 0.70.

**Figure 24: Likert response items averaged to create Ability variable**

| **2009 Ability Items** |
|---|
| • I can get an A in this class.<br>• I do well in math and science courses.<br>• I expect to get an A in this class.<br>• I already have a good understanding of chemistry from previous courses I have taken.<br><br>• The reverse scale of "I am not very good at Chemistry."<br>• The reverse scale of "Chemistry material does not come naturally to me."<br>• The reverse scale of "I have to work much harder than my peers to do well." |

**Support** represents the variable created to capture student perceptions of external support. The subscale labeled "Support" was created by averaging student Likert scale responses to the items listed below in Figure 25 (for complete factor analysis results see Chapter 4). The responses were coded 1=strongly disagree, 2=somewhat disagree, 3=somewhat agree, 4=strongly agree. Reverse scale in Figure 25 indicates student responses were considered to be the reverse of the scale above when coding them. All Support items have a factor loading of 0.3 or higher into their subscale (see Chapter 4). The Cronbach alpha reliability coefficient for the seven items used to create the Support variable is 0.67. Reliability was determined based on the factor loadings being above 0.30 and Cronbach alpha above or adequately close to 0.70.

**Figure 25: Likert response items averaged to create Support variable**

| **Fall 2009 Support Items** |
|---|
| • My friends believe in me.<br>• Someone in my family is always there for me.<br>• My family understands the struggles of studying science in college.<br>• My parents are proud that I am at UC Berkeley.<br>• I have people I can call for help when I have questions about chemistry.<br><br>• The reverse scale of "I do not have a great network of support."<br>• The reverse scale of "I do not have anyone to call when I am frustrated or overwhelmed with school." |

**EnvP** represents the variable created to capture student perceptions of the classroom environment at the beginning of the course. EnvP was a dummy variable created to indicate if a student expressed concerns about the course environment at the beginning of the semester. Students were asked to select their top three concerns from a given set of choices ranging from financial concerns, family situations, to class environment. EnvP was coded as 1 if a student selected a concern about the course environment above all other choices. If a student did not select one of these choices, relating to course environment as their top concern, then EnvP was coded as 0. The choices coded for expressing concern are listed below:

- The atmosphere at Berkeley is intimidating;
- The other students in the course are very competitive; and
- I feel overwhelmed by the courses at Berkeley.

Student major, socio-economic status (SES), ethnicity, and gender were collected by student self-report from the available options given. For major, SES, and ethnicity, the dummy variables represent the possible response options available to the students. Major "Physci_Math" was created as a combination of students who selected physical science or mathematics. Ethnicity "Mexican_Black" was created as a combination of students who selected Mexican/Mexican-American or African-American/Black. Ethnicity Otherasian was modified to include students who selected Japanese/Japanese-American and Seasian was modified to include students who selected Filipino. Ethnicity Other was created as a combination of students who selected Other, International Student, Middle Eastern, or Spanish/Spanish-American. Ethnicity Mixed was created to include all students who selected more than one ethnicity category. Below are descriptions of the dummy variables created to capture student demographic self-reports.

- Dummy variables created to represent major are: engineering (Engineering), physical science/mathematics (Physci_Math), humanities (Humanities), undeclared (Undeclared), other (Othermajor): with life science (Lifesci) as reference.
- Dummy variables created to represent SES are: Wealthy (SES_Wealthy), Upper-middle or professional middle (SES_Uppmiddle), Working-class (SES_Working), Low-income or poor (SES_Low): with Middle-class (SES_Middle) as reference
- Dummy variables created to represent ethnicity are: Chinese/Chinese-American (Chinesechineseamerican), East Indian/Pakistani (Eastindianpakistani), Korean/Korean-American (Koreankoreanamerican), South East Asian (Southeastasian), Other Asian (Otherasian), Mexican/African-American/Black (Mexican_Black), Students who indicated more than one ethnicity (Mixed), Other ethnicity (Otherethnicity): with White (White) as reference
- Dummy variable created to represent gender (Female): female=1, male or transgender=0

**Analytic Plan**

Multiple logistic regression analyses for ordinal responses were performed on student overall resource code collected at the beginning of the semester and their beliefs about their academic abilities (Ability), perceptions of external support (Support), perceptions of the classroom environment (EnvP), and demographic dummy variables for major, SES, ethnicity, and gender. For comparison, a student's first exam score was regressed on student behavior (Overall Resource Code) along with student perceptions (Support, EnvP) and demographic dummy variables. Student beliefs about learning science was not included in this analysis since there were concerns that the items used to create this variable did not capture the intended belief. Full details of how these variables were created and evaluated are given in Chapter 4. The two models used in the analysis are outlined below.

Model A evaluates the effects of student belief (Ability) and perceptions (Support, EnvP) on their overall resource use code including demographic variables for control. This is later used to determine if use of resources acts as a mediator as shown in Logic Model 1.

Model A (mediating, Logic Model 1)

$(\text{Overall Resource Use Code})_i = \beta_1(\text{Ability})_i + \beta_2(\text{Support})_i + \beta_3(\text{EnvP})_i + \beta_4(\text{Engineering})_i + \beta_5(\text{Physci\_Math})_i + \beta_6(\text{Humanities})_i + \beta_7(\text{Undeclared})_i + \beta_8(\text{Othermajor})_i + \beta_9(\text{SES\_Wealthy})_i + \beta_{10}(\text{SES\_Uppmiddle})_i + \beta_{11}(\text{SES\_Working})_i + \beta_{12}(\text{SES\_Low})_i + \beta_{13}(\text{Chinese})_i + \beta_{14}(\text{Eastindianpakistani})_i + \beta_{15}(\text{Korean})_i + \beta_{16}(\text{Southeastasian})_i + \beta_{17}(\text{Otherasian})_i + \beta_{18}(\text{Mexican\_Black})_i + \beta_{19}(\text{Mixed})_i + \beta_{20}(\text{Otherethnicity})_i + \beta_{21}(\text{Female})_i$

Model B evaluates the direct effects of student perceptions (Support, EnvP) and overall resource use code on course exam score when evaluated together. Demographic variables are used in this model for control.

Model B (direct effects, Logic Model 2)

$(\text{ExamPercentile})_i = \beta_1 + \beta_2(\text{Overall Resource Use})_i + \beta_3(\text{Support})_i + \beta_4(\text{EnvP})_i + \beta_5(\text{Engineering})_i + \beta_6(\text{Physci\_Math})_i + \beta_7(\text{Humanities})_i + \beta_8(\text{Undeclared})_i + \beta_9(\text{Othermajor})_i + \beta_{10}(\text{SES\_Wealthy})_i + \beta_{11}(\text{SES\_Uppmiddle})_i + \beta_{12}(\text{SES\_Working})_i + \beta_{13}(\text{SES\_Low})_i + \beta_{14}(\text{Chinese})_i + \beta_{15}(\text{Eastindianpakistani})_i + \beta_{16}(\text{Korean})_i + \beta_{17}(\text{Southeastasian})_i + \beta_{18}(\text{Otherasian})_i + \beta_{19}(\text{Mexican\_Black})_i + \beta_{20}(\text{Mixed})_i + \beta_{21}(\text{Otherethnicity})_i + \beta_{22}(\text{Female})_i$

where i=individuals (1,2,3….61 interview participants)

## Results and Discussion

*Descriptive Statistics*

Descriptive statistics for each belief, perception, behavior, and exam variable are shown in Tables 24-27 below. Descriptive statistics for the demographic dummy variables used for control were shown earlier in Table 22.

**Table 24: Descriptive statistics for continuous student beliefs and perceptions variables.**
Mean (M) and standard deviation (SD) computed from responses are shown for the full sample population as well as the analysis group. The analysis group is the subset of 61 students from the course who participated in interviews and were included in the current analysis. Full sample populations are shown for reference. ($N_{2009}$=428 ; $N_{analysis\ group}$=61)

| Variable | Analysis Group | | Fall 2009 Sample | |
|---|---|---|---|---|
| | **Mean** | **SD** | **Mean** | **SD** |
| Ability | 2.86 | 0.65 | 2.76 | 0.56 |
| Support | 3.27 | 0.44 | 3.21 | 0.45 |

**Table 25: Descriptive statistics for dichotomous student perception variable.**
Number of students (N), and percent of sample population (%) represented by each response option are shown for the full sample population and for the analysis group. Analysis group is the subset of 61 students from the course who participated in interviews and were included in the current analysis. Full sample population is shown for reference. ($N_{2009}$=428 ; $N_{analysis\ group}$=61)

| Variable | Category | Analysis Group | | Fall '09 Sample | |
|---|---|---|---|---|---|
| | | **N** | **%** | **N** | **%** |
| **EnvP** | Expressed Concern towards classroom environment (1) | 14 | 23.0 | 121 | 28.3 |
| | Did not express concern towards classroom environment (0) | 47 | 77.1 | 307 | 71.7 |

**Table 26: Descriptive statistics for continuous response variable.** Exam percentile is computed based on a student's first exam in the course. Minimum (Min), maximum (Max), mean (M), and standard deviation (SD) computed from responses are shown for the full sample population as well as the analysis group. The analysis group is the subset of 61 students from the course who participated in interviews and were included in the current analysis. Full sample population is shown for reference.
( $N_{2009}$=428 ; $N_{analysis\ group}$=61)

| Variable | Analysis Group | | | | Fall 2009 Sample | | | |
|---|---|---|---|---|---|---|---|---|
| | **Min** | **Max** | **M** | **SD** | **Min** | **Max** | **M** | **SD** |
| **ExamPercentile** | 0.8 | 98.3 | 53.1 | 29.4 | 0.3 | 99.8 | 53.7 | 27.5 |

**Table 27: Distribution of students into each use of resource category.** Number of students (N) and percentage of analysis group (%) assigned into each overall resource code level represent students at the beginning of semester. The analysis group is the subset of 61 students from the course who participated in interviews and were included in the current analysis. ($N_{Total}$ = 61)

| Overall Resource Code | Number of Students (N) | Percent of Sample (%) |
|---|---|---|
| 1 | 8 | 13.1 |
| 2 | 45 | 73.8 |
| 3 | 8 | 13.1 |
| 4 | 0 | 0.00 |

*Relationship between student use of resources, beliefs, perceptions, and course performance*

The multiple logistic regression model used to generate Model A (Mediating, Logic Model 1) estimated how student beliefs, perceptions, and demographics related to student overall resource use level (see Table 28 for results). The regression model used to generate Model B (Direct Effects, Logic Model 2) estimated how student behavior, perceptions, and demographics related to student exam score (see Table 28 for results). The effects of each variable in the model were evaluated based on odds ratios (Model A) and coefficients (Model B) computed and the corresponding p-values or level of significance. Variables were considered to be significant if their p-value was <0.05, or 5%. All estimates reported were calculated with control variables which include demographics.

*Effects of Student Beliefs and Perceptions on Use of Resources*

Model A in Table 28 reports the findings of the multiple logistic regression model evaluating the effects of student beliefs and perceptions on students use of resource. The estimated odds of having a higher overall use of resources code was significantly affected by student beliefs in their academic ability in chemistry. For each one unit increase of student beliefs in their academic ability, the odds of using behavior characteristic of a higher overall resource code were estimated to increase by 9.78% (z=2.23, p=0.026). Student perceptions of external support and perceptions of the classroom environment did not significantly affect student odds of having a higher or lower overall resource code (Support z=-1.48, p=0.139; EnvP z=1.56, p=0.118).

*Model A Student Demographic Characteristics*

Two of the ethnicity dummy variables in model A (Table 28) were found to significantly affect the odds of having a higher overall use of resource code. Compared with students of white ethnicity, the odds of having a higher overall resource code decrease by 99% for students of Korean ethnicity (z=-2.02, p=0.043) and decrease by 98% for students of Mexican or African-American ethnicity (z=-2.11, p=0.034).

*Effects of Use of Resources and Perceptions on Exam Performance*

Regression analysis was performed to test for some of the direct effects shown in Logic Model 2 (Figure 22). The estimates from this regression are shown in Model B (Table

28). Given that results from Model A showed that student perceptions of external support and perceptions of the classroom environment did not have a significant impact on student overall use of resources, these variables were included, along with the overall use of resource code and demographic variables in Model B, to predict student exam performance. Regression analysis found that the coefficient for student overall use of resources was significant at the 5% level. As the code for student overall use of resources increases, so does exam performance ($\beta = 25.67$, $p < 0.001$). The measures for student perceptions of external support and perceptions of the classroom environment were not found to predict exam scores significantly at the 5% level when included in this model.

*Model B Student Demographic Characteristics*
Two of the demographic dummy variables were found to have significant coefficients in this model. When compared with students of SES middle-class, students who report an SES of upper-middle class have a higher mean exam score ($\beta = 14.79$ , $p = 0.031$). Students of ethnicity "other asian" have a higher mean exam score than the reference category (white) ($\beta = 33.16$ , $p = 0.015$).

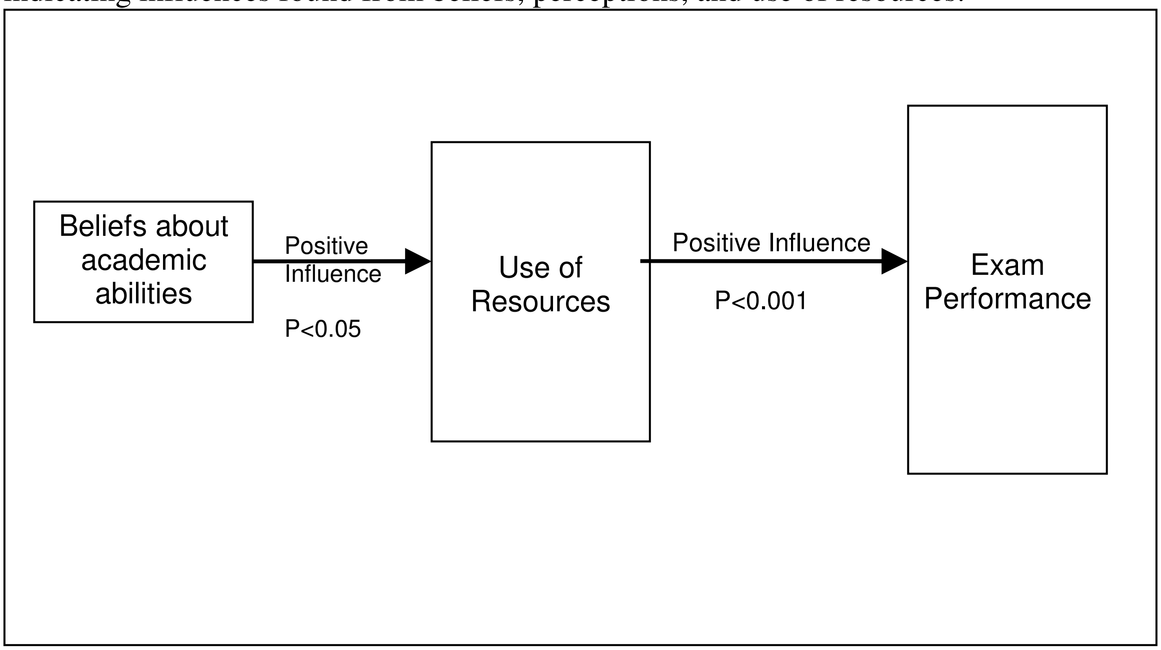
**Table 28: Estimates for Student Beliefs and Perceptions Effects on Use of Resources and Exam Performance.** Standard errors (SE) are shown for computed odds ratio and estimated coefficients (Coef). Model A evaluates the effects of student beliefs (Ability) and perceptions (Support, EnvP) on their overall resource use code. Model B evaluates the direct effects student perceptions (Support, EnvP) and overall resource use code have on course exam score when evaluated together. Demographic variables are used in each model for control. ($N_{Total}$ = 61)

| | **Model A: Effects of Beliefs and Perceptions on Use of Resources** | | **Model B: Effects of Use of Resources, and Perceptions on Exam Performance** | |
|---|---|---|---|---|
| | **Odds Ratio** | **SE** | **Coef** | **SE** |
| Constant | | | 23.45 | 30.48 |
| **Overall Resource Code** | | | 25.67** | 6.27 |
| **Circumstances** | | | | |
| Ability | 9.78* | 9.99 | | |
| Support | 0.19 | 0.22 | -12.23 | 7.75 |
| EnvP | 5.55 | 6.08 | 2.49 | 7.81 |
| **Demographics** | | | | |
| Engineering | 3.76 | 4.56 | 15.72 | 8.13 |
| Physci_Math | 20.24 | 33.88 | 19.42 | 12.00 |
| Humanities | 7.80 | 17.22 | -24.78 | 13.56 |
| Undeclared | 3.10 | 4.52 | 8.85 | 10.84 |
| Othermajor | 9.17 | 14.73 | -1.88 | 12.29 |
| SES_Wealthy | 0.22 | 0.96 | 38.73 | 26.27 |
| SES_Uppmiddle | 0.20 | 0.17 | 14.79* | 6.59 |
| SES_Working | 3.53 | 5.34 | -13.55 | 11.56 |
| SES_Low | 6.05 | 9.69 | 9.44 | 12.70 |
| Chinese | 0.25 | 0.28 | 11.85 | 8.12 |
| Eastindianpakistani | 0.60 | 1.09 | 19.01 | 12.43 |
| Korean | 0.01* | 0.03 | 7.01 | 15.72 |
| Southeastasian | 0.06 | 0.10 | 21.17 | 13.56 |
| Otherasian | 2.11 | 4.14 | 33.16* | 12.99 |
| Mexican_Black | 0.02* | 0.03 | -3.80 | 14.42 |
| mixed | 0.14 | 0.32 | 29.72 | 17.04 |
| Otherethnicity | 0.07 | 0.12 | -3.28 | 16.29 |
| Female | 0.34 | 0.35 | -4.16 | 7.46 |

* $p<0.05$ ** $p<0.001$

*Implications of these findings*
This chapter found the answer to the third research question "How do beliefs and perceptions impact student behavior towards use of resources and student course performance?" The findings from this analysis are summarized in the logic model shown in Figure 26. Student use of resources was found to mediate the effects of student beliefs about their academic abilities on course performance. This was determined by a comparison of results from Model A (mediating, Logic Model 1) and Model B (direct effects, Logic Model 2).

**Figure 26: Illustration of final logic model.** Based on findings from this analysis indicating influences found from beliefs, perceptions, and use of resources.




Model A evaluated the effects of student beliefs (Ability) and perceptions (Support, EnvP) on their overall use of resources code. Additionally, Model A was used to determine if student use of resources acted as a mediator between student beliefs and perceptions and course performance. Results from the analysis show that student use of resources mediated the effects of student beliefs in their abilities on their exam performance. This was determined by the significant effect of student beliefs in their abilities on overall use of resources level. Since neither student perceptions of external support nor student perceptions of the classroom environment were found to have a significant effect on use of resources, only the direct effect of student beliefs in their abilities was considered to be mediated by use of resources.

Model B evaluates the direct effects of student perceptions (Support, EnvP) and overall use of resources on course exam score when assessed together. Student beliefs in their academic abilities was not included in this model since Model A revealed its direct effect on exam performance was mediated by use of resources. Student perceptions of external support and perceptions of the classroom environment were eliminated as predictors of exam performance in the final logic model (Figure 26), since they were not found to be significant at the 5% level in Model B.

While student perceptions are determined to have no significant impact on course performance from this analysis, the hypothesis that a student's success is influenced by the student's beliefs and behavior in the course is supported. These findings expand the current literature by suggesting an explanation behind the effect of student beliefs in his/her abilities on performance in undergraduate chemistry. This explanation is captured by the mediating role of use of resources in the final logic model (Figure 26). This mediating role suggests that increased beliefs in their ability will influence students to use resources more effectively, which results in better exam performance. This also supports previous findings that suggest a need to consider how belief in their abilities will influence students' goals and will impact students' achievements (Britner & Pajares, 2006).

## Chapter 8: Three Case Studies Exploring Students Use of Resources and Development of Scientific Thinking

### Introduction

The analysis of three case study interviews is described to explore evidence correlating student behavior towards use of resources with development of scientific thinking. Specifically, these case studies were used to answer the fourth research question: "Does student use of resources correlate with understanding of chemistry concepts or development of scientific thinking in introductory chemistry?"

Three students who exemplify and span the range of use of resources levels were selected. These students also demonstrated a positive trajectory of resource use over the semester. This detailed analysis of the three students' initial and final behaviors provides insight into the differences between use of resources at varying levels, the links between use of resource levels and course performance, and motivations influencing change of use of resources over the semester. Focusing on three main sections of each of the students' interview, this study provides:

1) Analysis of each student's initial interview when they discuss how they studied for the first exam in the course. This is used to exemplify how students approach learning with respect to different use of resource levels.
2) Analysis of a section of the first interview when students were discussing their understanding of boiling point. Based on their level of demonstrated understanding, explanations are proposed for correlation between student use of resources and learning of the course content.
3) Analysis of students' description during the final interview of the most significant changes in their behavior towards use of resources over the semester.

### Rationale

Literature review describing the development of scientific thinking and possible link between student behavior when learning and success in development of scientific thinking is summarized below.

*Development of Scientific Thinking*

The term "scientific thinking" in this study refers to the ability of a student to use atomic level models and descriptions in explaining links between multiple phenomena in chemistry. This definition of scientific thinking was motivated by research describing the Knowledge Integration Learning Perspective (Linn, 2006). Knowledge Integration found its roots in the growing themes identified through review of research in developmental, sociocultural, cognitive, and constructivist perspectives (Linn & Eylon, 2006). Studies of students working to generate a coherent explanation by resolving conflicting ideas were conducted which resulted in the formulation of the knowledge integration perspective. The knowledge integration perspective characterized learners as "developing a repertoire of ideas, adding new ideas from instruction, experience, or social interactions, sorting out these ideas in varied contexts, making connections among ideas at multiple levels of analysis, developing more and more nuanced criteria for evaluating ideas, and formulating an increasingly linked set of views about any phenomena" (Linn, 2006, p.

243). The definition of scientific thinking in this study is consistent with the view of learning as a process of identifying, linking, and evaluating related ideas to explain scientific phenomena. The term scientific thinking in this study is more specific to chemistry since it specifies the inclusion of atomic level models and descriptions in the formation of links, or connections, to create an understanding of related phenomena.

*Behavior towards Use of Resources*

To better understand how students learn chemistry, we reviewed several curricular approaches developed and evaluated for their effective use within the classroom. These approaches indicated effective development of scientific thinking. Similar methods were found to be effective if used outside the classroom when developing the use of resources framework for chemistry (see Chapter 6). The approaches include student use of explanations (Hunt & Minstrell, 1994; Teichert & Stacy, 2002), cognitive apprenticeship or training (Chiu, Chou, & Liu, 2002), and the MORE thinking frame (Tien, Teichert, & Rickey, 2007). Additionally, various computer modules which integrate visualization tools that allow students to learn through exploration of the models have also proven effective (Levy & Wilensky, 2009; Linn, Lee, Tinker, Husic, & Chiu, 2006; Pallant & Tinker, 2004). These computer modules incorporate elements of the Knowledge Integration Framework for Instruction (Linn, Davis, & Eylon, 2004). The modified curriculum used during this study is aligned with these approaches. One common theme in the aforementioned approaches is the emphasis on instruction that more explicitly addresses the molecular level models to explain concepts, along with prompting students to explain phenomena using these molecular level ideas.

When compared to the Use of Resources Framework developed in Chapter 6, many of the behaviors characterized as levels 3 and 4 shared similarities with effective curricular strategies reviewed. For example, student's use of self explanation (Teichert & Stacy, 2002) shares this common idea of students translating ideas into their own words. Levels 3 and 4 behaviors include elements from the four meta-principles outlined in the knowledge integration framework for instruction (Linn et al., 2004). To make science accessible, levels 3 and 4 students begin to deviate from the given text and apply the ideas they are learning to explain familiar phenomena. A level 4 student asks the question "How does this apply to what I see in the world?". To make thinking visible, a level 2 student realizes there are connections they are not making with the material. This awareness demonstrates how they are starting to make their thinking visible to themselves. Level 3 and level 4 students take this a step further and evaluate their ideas independently as well as through interactions with peers. This transition to evaluating ideas between peers is also evident in how level 3 and level 4 students are learning from others in a less passive and more effective way. By not just relying on peers for answers, these students are using peer interactions to generate their own understanding through connections between ideas. Students' increased use of metacognition at higher levels demonstrates a promotion of autonomy.

These links to the effective curricular strategies reviewed, and elements of the modified curriculum used in this course, suggest these curricular elements imply their extension to learning outside of the classroom. Students characterized at a higher use of resource level appear to incorporate more of these strategies. Given this, students who employ more behaviors incorporating these strategies may have more success in developing scientific thinking when learning outside of the classroom.

**Figure 27: Summary of Use of Resources Framework levels.** Used to characterize students approaches to use of resources by level (see Chapter 6 for full details).

| Level | Description |
|---|---|
| 4<br>Researcher | Taking in the information, questioning why this is true and how it helps to explain the world around them.<br>**Asking: How does this apply to what I see in the world?** |
| 3<br>Critical Thinker | Evaluating information and questioning why. More independent as a learner, trying to give their own explanations.<br>**Asking: Am I thinking about this correctly?** |
| 2<br>Procedural | Taking in the information and making small connections. Still relying on others or course materials for answers.<br>**Asking: How do you do this?** |
| 1<br>Memorizer | Memorizing independent facts.<br>**Asking: What is the answer?** |

## Methods

*Selection of Students*
Three students were selected for case studies. These students were chosen because they represent different use of resource levels identified in the Use of Resources Framework (see Figure 27 above) and each demonstrated a shift to a higher use of resource level over the semester. Students who did not demonstrate changes in their use of resources or shifted to a lower level were not considered to be as informative for the purposes of this analysis. The overarching goal is to understand possible paths taken by students who shifted their use of resources to become more effective learners. This decision was based on previous findings that students who are classified as using resources at a higher level, on average, demonstrate higher exam scores, and therefore possibly develop a deeper understanding of the material covered in the course (see Chapters 6 and 7 for full details). That the three students selected are male was not intentional, as the selection was based on student use of resources over the semester and on interview quality.

Student A performed in the bottom 10th percentile of the class on exams. He was characterized in his use of resources as moving from a level 1 to a level 2 over the semester. While his exam scores remained low throughout the semester, he was characterized as making a positive shift in his use of resources. His low exam scores may be due in part to a need for time to review the earlier content from when he was using resources at a level 1. Review of this content using a level 2 approach might help develop a more complete foundation to build from.

Student B made gains on his exam scores. Scoring near the 20th percentile on his first exam, he scored near the 40th percentile on exams 2, 3, and 4. Scoring in the 90th percentile, he improved significantly on the final exam for the course. Student B was characterized in his use of resources as moving from a level 2 to a level 3 over the semester.

Student C performed above the 90th percentile on all exams in the course. He was characterized as moving from a level 3 to a level 4 in his use of resources over the semester.

*Video Analysis*

Two sections from each student's first interview, collected at the beginning of the semester, and one section from each student's end of semester interview were chosen for this analysis. In the first part of each interview the students were asked about how they had studied for the recent exam. After describing their approach to studying in the first interview, students were asked to explain their thinking on question 19 of their recent exam. The exam question about boiling points (see Figure 28) was used to prompt the students to explain their understanding of why two different substances have different boiling points and to describe what is happening when a substance boils. A copy of the exam with their original response was given to them for reference. In the final interview students were prompted to discuss what they perceived as the most significant changes they had made to their use of resources (study habits) over the semester.

Two main reasons drove the decision to focus on the first interview when each student described their use of resources. The first reason was the level of detail each student provided. Since this was the first time the student and interviewer were meeting, the student was more inclined to elaborate on his strategies and what he did or did not do. In later interviews each student made many references back to their initial descriptions saying such things as "nothing has really changed" or "yeah I did pretty much like before". These later interviews provided less depth since the student felt they had already described their behavior.

The second reason was grounded in the timing of the interview. Since the first interview asked them about how they had studied for the first exam, they had not yet had a chance to adjust to the course exam style. This allowed for insight into what strategies students initially brought with them into the classroom. Additionally, students had not yet made any adjustments to their responses to align with what they perceived to be the course expectations. In later interviews, when they described how they used course resources, some students appeared to have adopted ideas presented by the professors and other course staff. In some cases, it was difficult to distinguish whether these ideas were being truly incorporated by students when studying or were being aligned with instructor's expectations.

The correlations identified between their use of resources and their thinking about the exam question on boiling points were used to demonstrate how their use of resources may have an effect on their understanding. Students who take a more active and engaged approach to their use of resources in the course should demonstrate a deeper understanding of the material. This development of a more complete understanding should be evident through the increased use of atomic level models to explain how different characteristics of the molecules relate to explain phenomena.

An analysis of their description of the most significant changes made, as revealed in the final interview, provides insight into how they changed their use of resources over the semester. During the second interview, students were still struggling to implement changes to their use of resources and at the same time adjusting to college life. In the final interview at the end of the semester, students provided a more retrospective account. By the end of the semester, these students appeared to be fumbling less when attempting to determine which changes were effective. They were believed to have had enough time to evaluate their changes and decide which changes they felt were helpful in meeting their learning goals. Since the three students selected for this study made a transition over the semester to a use of resource level that was higher than where they started, the changes they described are exemplary of transitions considered beneficial and are to be encouraged.

**Figure 28: Exam item #19 used to explore student understanding of boiling point**

| |
|---|
| 19. Explain why methanol, $CH_4O$, has a higher boiling point than formaldehyde, $CH_2O$.<br>Provide Lewis dot structures to justify your answer. |

**Participants**
Participants were students enrolled in the introductory chemistry course at a large public university. This course enrolls approximately 1300 students each Fall semester. This course is designed for non-chemistry majors who need to take chemistry as a pre-med or major requirement.

**Results and Discussion**

**Student A, Level 1 to 2**
*Initial use of resources analysis for student A*
Student A is characterized as taking a very passive approach to his learning. He describes a reliance on external sources to shape his understanding and to find answers. He appears to approach his learning as one-directional, where a source of knowledge conveys information to him, the student. He describes that a student's role is to absorb the information presented without question.

Early in the interview student A admitted that on the day of the first exam he had thought about not attending the exam. Later in the day, after reading the textbook a bit, he then decided to take the exam. Based on this conversation, the interviewer asked him about how he prepared for the exam.

1. I: so you said you weren't going to take the test… how did you prepare for the midterm, or did you prepare?
2. A: yeah ummm they posted old midterms so me and a couple of my friends tried to do them you know but they all took AP chem. and stuff like that so and I am guessing their school was probably more academically motivated than ours so ahhh they all had, they all had like prior

knowledge of chem. but I didn't know anything about it so I'm just sitting there and they're just saying this this and that and this and then I'm like yeah ok, ok yeah

3. I: did you ask them questions on things you didn't understand or did you more in your head say I wish I knew that, I wish I knew that?
4. A: yeah yeah yeah that right there and ahhh that one, I wish I knew that …yeah that one....oh oh and about an hour before the test that's probably just why I got all the boiling point stuff because I just went back into the chapter and just started reading on the boiling point
5. I: So why did you choose not to ask them questions?
6. A: because, I don't know why…..probably because I didn't want to feel like a burden to them because they were also trying to study for their midterm and that if I started asking them one question I would just continuously keep asking them questions and then they probably wouldn't be able to complete studying

Student A begins by describing his working with a group of students to review past midterms that had been posted online. In line 2, he describes not understanding the material being covered by the group when he states "but I didn't know anything about it so I'm just sitting there and they're just saying this this and that and this and then I'm like yeah ok, ok yeah". Later, when asked his reasons for not asking these peers to explain what was happening, student A states in line 6 "probably because I didn't want to feel like a burden to them....." and then "....if I started asking them one question I would just continuously keep asking them questions". He does not appear to realize the value of his peers taking time to explain their thinking to him. He admits to being hesitant to ask questions of his peers because this would interrupt their learning. His responses demonstrate a focus on answering the questions presented but do not mention the larger picture of understanding the process. He makes no reference to recognizing that if he asked his peers to explain their work, it would not only help himself, but challenge his peers to explain their thinking and the concepts involved with answering each question.

7. I: did you try any of the problems on your own at any point?
8. A: no........ no, no
9. I: you said you looked through the book, did you look back over any of the OWL problems?
10. A: no, OWL, I just do OWL and I never look back at that thing. I am sick of that thing.
11. I: did you look over any of the lecture slides before the exam?
12. A: I looked over my notes yeah, some of my notes, but they weren't very helpful to me
13. I: where were your notes? did you print out the lecture slides and take notes?
14. A: oh no, they were just hand written. I just started printing out the lecture slides now

21. I: so thinking about how you studied what do you think helped you the most?
22. A: well I just skimmed through the chapter and read what I thought was important and relevant to the class and just tried to skip all the extra information

In line 8 he states that he did not try to do any of the problems on his own. He does not appear to give any description of assessing his own ability through solving problems. Student A describes his use of the textbook in line 22, "I just skimmed through the chapter and read what I thought was important and relevant to the class and just tried to skip all the extra information." His intent appears to be using the text to gain a more definitional understanding of the material. He does not describe attempting to internalize or translate the information into his own words. His description is limited to taking in facts and explanations.

15. I: did you go to any of the review sessions?
16. A: I went to the first one where they were talking about stoichiometry but it didn't really help me much because most of the people in there already had prior knowledge so then after that I went over to a little chem study thing at (the dorm) and I don't know, I did not get that, so there is a kid named W who lived on my floor who is like a genius in chem and he is the one who always helps me out with the OWL and so I just go to him
17. I: did you go to any of the office hours?
18. A: yeah I went to one of my GSI's and it was in B12 but there were a lot of people in there so it was hard to ask questions so I just left
19. I: do you go to the SLC?
20. A: I heard of the SLC study group, they offer chem P right? (interviewer clarifies that they offer help for various chem courses) well I heard you have to sign up online and I never got to do that

23. I: you mentioned your friend W down the hall helped you, define "helped"
24. A: help is how he explains things. To tell you the truth, no offense to the teachers, but he explains it a lot better than how the teachers explain it. He gives me like a visual in my head and he will teach me the stoichiometry parts, he will explain to me every part of a problem not just saying like ...so lets say something about formal charges he will tell me how to figure out the formal charges, how to draw it so I can figure out the formal charges, and then - I don't know how to explain it- he just........
25. I: so does he break it down and go piece by piece
26. A: yeah and he tutored chem in high school so he knows a lot
27. I: when he is helping you does he also kinda give you the answer or more just the tools to get to the answer?
28. A: he gives me the tools to get to the answer but then along with just giving me the tools he will watch over me while I am doing the problem and then he won't directly tell me that I am suppose to put this here or this here but he will guide me after he has already given me the tools to reach the answer. But he won't give me the answer

He appears to focus on getting answers to specific questions when referencing learning from his peers or GSI. In line 18 he talks of attending office hours "...but there were a lot of people in there so it was hard to ask questions so I just left". He does not appear to value listening to other student questions, but instead describes focusing on finding answers to only his own questions. When asked how another student is able to help him, he states in line 28 "he gives me the tools to get to the answer but then along with just giving me the tools he will watch over me while I am doing the problem and then he won't directly tell me that I am suppose to put this here or this here but he will guide me after he has already given me the tools to reach the answer. But he won't give me the answer". This description of what he feels is necessary to help him understand the material is interpreted in this analysis to reveal his dependence on others to help him find the answers. He does not convey satisfaction with presentation of the information alone, but instead requires step-by-step instructions and guidance to solve a problem. He appears to heavily rely on external sources for information and guidance rather than looking to himself as capable of making connections between the information to solve problems. He makes no reference to seeking answers to understand the general process or the underlying theory justifying the answer. He is concerned with just the specific path for answering specific questions.

*Explanation of boiling points and the possible correlation with use of resources for student A*

Student A seems to rely on memorized facts and definitions when describing his thinking about the exam question on boiling points. He does not appear to have a clear explanation; instead, he pieces together facts he recalls being told that appear relevant. This correlates with his described level 1 use of resources, wherein he focuses on memorization and passively accepts facts given to him. The passive behaviors towards use of resources that he describes in this interview are correlated with his understanding, which appears to consist of recalled information without any indication of attempts to include self-generated explanations.

Prompted by the interviewer to explain his answer to item 19 of his exam, student A recalls his thought-process and explores his understanding of boiling points in the following excerpt:

29. A: [reads problem aloud] my thought was because oh yeah you see that right there (points to lewis structure of methanol) that I did not take off my own thing they had a picture of it somewhere else (earlier in the exam-shows where) but umm the reason I said it had a higher boiling point is I remember one of the lecture professors saying that if it weighs more or has a higher molecular mass then it has a higher boiling point but there was also something else that had to do with that that I didn't remember so that's all I said [reads over original answer written on exam again]
30. I: so what does boiling point mean to you
31. A: boiling point means the temp at which the ummm…..no that's equilibrium… boiling point is the temp at which the gas molecules are able to break through the surface of the liquid ...or is boiling point the temperature at which the pressure outside, yeah, I think that's it… when the pressure outside is equal to the pressure inside…is that it?
32. I: I don't know I am asking you. So when you think about that, you mentioned molecular mass and the structure, how does that connect with your definition of boiling point?
33. A: well the $CH_4O$ and the $CH_2O$ are practically the same other than the $CH_4O$ just has 2 more hydrogens so honestly it weighs more and so the thought ran through my mind that ok if it weights more than $CH_2O$ that means .....oh and also since it has more atoms of H then their is a stronger bond, I can't think of it, oh yeah a stronger hydrogen bond which also increases boiling point.
34. I: so tell me more about this hydrogen bond, what is that?
35. A: I guess that a hydrogen bond is when hydrogen is connected to either chlorine, oxygen, or nitrogen and whenever hydrogen is connected to one of those then it makes a hydrogen bond and it's suppose to be strong
36. I: do you have any reason why it would be strong?
37. A: no I just memorized that. that is what it is

This section of his response appears to indicate his dependence on recall of facts presented to him. Upon reading his original answer on the exam, he seems to quickly move to the words of the professor, saying "I remember one of the lecture professors saying that if it weighs more or has a higher molecular mass then it has a higher boiling point" (line 29). In line 31 student A seems to be trying to recall the definition of boiling point from his reading. Line 37 provides a description of his understanding of hydrogen bonding and exemplifies his use of resources when he states "no I just memorized that". This response does not indicate any evaluation towards the facts he is stating. His explanation is simply a recall of facts and definitions. His admission in line 29 further demonstrates his dependence on outside sources, "you see that right there (points to lewis structure of methanol) that I did not take off my own thing they had a picture of it somewhere else (earlier in the exam-shows where)".

When prompted by the interviewer to explain this in more detail, in an attempt to push student A to move beyond restatement of facts, the student describes many misconceptions concerning hydrogen bonding and boiling.

38. I: so how does that play into boiling point?
39. A: because the stronger the bond is makes it the stronger the structure inside and so it makes it harder for the gas molecules to escape because they have to be going at a higher or faster speeds and since they have to be at faster speeds in order to break through the surface......
40. I: if I had a puddle of methanol and was heating it on a hot plate, and I could zoom in and see just ten of the molecules in there, what would I see happening as it's heated up?
41. A: the molecules would just start moving around everywhere and then as temperature increased they would start moving around faster and faster which means pressure would increase and eventually some of the molecules as it reached the boiling point would start to break through the surface of methanol
42. I: so add hydrogen bonding into that picture
43. A: the boiling point would increase because the structures that the ten molecules have to break through are like the structures are a lot more concrete and they are a lot more combined or compacted which makes the structure for the molecules to break through a lot harder which means the pressure has to be higher and the temperature has to be higher
44. I: and when you say compacted, are the molecules themselves more compact or what part is compact?
45. A: the intermolecular structure of the molecule
46. I: so the molecule itself or multiple going out?
47. A: what do you mean multiple going out?
48. I: are you meaning the 10 are closer together or each individual one would be shrunk?
49. A: yeah the individual
50. I: so how do some become gas?
51. A: when water reaches a certain temperature it becomes a solid and when it reaches a certain temperature it becomes liquid or gas. So some of them reached a certain temperature
52. I: so if I looked at 10 liquid molecules and 10 gas molecules what would be the difference in what they look like?
53. A: the liquid would be much closer together and the gas molecules would be much farther apart
54. I: and so how does that happen though when they started out as liquid, a little puddle, how do they become gas from that?
55. A: I am guessing because they moved farther apart
56. I: are their speeds any different between the two?
57. A: yeah the speeds increase
58. I: and what makes them increase?
59. A: the temperature

In line 43, when he includes hydrogen bonding in his description, he suggests it increases the bond strength when he states "...the structures are a lot more concrete and they are a lot more combined or compacted". When asked to clarify the meaning of "more compacted", student A responds in line 45 with "the intermolecular structure of the molecule". Student A does not present a clear self-generated picture at the atomic level. Instead, he continues to respond with statements of facts provided from textbooks such as "when water reaches a certain temperature it becomes a solid and when it reaches a certain temperature it becomes liquid or gas. So some of them reached a certain temperature" (line 51). In line 55 he states that molecules, starting as liquid, become a gas "because they moved farther apart". Student A appears to recall facts about the distance between molecules at the atomic level in different states but offers no connection between the phenomena of heat, molecular speed, and phases.

This lack of connections between facts in his explanations may be caused by his inability or lack of awareness that these facts are connected through underlying theories to explain the given phenomena. Instead, he appears to be approaching the content as a set of definitions to memorize and restate. His descriptions consist of relevant statements he can recall for a given question but do not include any indication of understanding what they depict happening between molecules. This apparent lack of ownership towards the content correlates with his described view that the knowledge should be told to him by an "expert" or a more experienced individual on the subject.

*Use of resources shift: moving from a 1 to a 2 over the semester*
Student A made a transition over the semester from being characterized as a level 1, memorizer in his use of resources, to a level 2, more procedural learner. His summary of the change is exemplified in line 65 where he states, "I just wanted to memorize it all but then I figured out that there was just way too much to memorize so probably learning how this thing and this thing combines to work together would probably make this thing over here a lot easier to understand". He also references reviewing homework assignments in line 61 which was interpreted as indicative of taking a more active role. In his first interview, when asked about homework assignments, he stated "no, OWL, I just do OWL and I never look back at that thing" (line 10). This change, described as reviewing homework assignments, is characterized as a step towards taking ownership of his knowledge. Possibly realizing a goal of more than finding the answer, he is moving towards understanding the process. Believed to rely heavily on others, his changes appear to be a product of peer influence. In line 67 he references his friend saying "...my friend W told me that I needed to understand why these things worked as opposed to just knowing them".

60. I: what were the most significant changes you have made in your study habits this semester?
61. A: ummm reading the book…no no no no sorry that just confused me even more ….probably starting to do past OWL assignments over again and going to review sessions
62. I: what made you start to do these things and why?
63. A: probably what made me start to do them was the need for a better grade and the need to understand more, I needed to understand the concepts and the way things worked and not just be able to just memorize them
64. I: do you feel like at the beginning you were just trying to memorize them?
65. A: I just wanted to memorize it all but then I figured out that there was just way too much to memorize so probably learning how this thing and this thing combines to work together would probably make this thing over here a lot easier to understand.
66. I: when did this happen?
67. A: I think during midterm 3 since that is when I started to do the past OWL assignments and tried to understand more. Also my friend W told me that I needed to understand why these things worked as opposed to just knowing them.
68. I: do you feel like you work more with W now or has that changed over the semester?
69. A: I think that I do work a lot more with him now. For the final we started on Saturday or Sunday, I am not sure which day, we are starting to do all the OWL's all over again. And we just work together every day now.

Student A exemplifies a progression from a level 1 to a level 2 use of resources based on his initial and final interview. His level 1 behavior appears to correlate with his reliance on recalled facts in explaining his understanding of boiling points during his first interview. The main changes identified in his use of resources over the semester are his increased ownership of knowledge and his awareness of the need to do more than just memorize facts. He still displays a reliance on others for learning at the end of the semester, but begins to appear more independent. This change over the semester is attributed to peer influence, as he follows the advice of another student.

**Student B, Level 2 to 3**

*Initial use of resources analysis for student B*

Student B is considered less passive than Student A. Student B references testing his abilities through problem solving. Not appearing to trust his own judgment, he describes relying on external sources to describe concepts to him. The role he describes as a student is characterized as first taking in information, and then practicing how to use information in answering questions.

Student B admits during the early part of the interview to having mixed feelings about his performance on the first exam in the course. He conveys awareness that he could have been better prepared but also that he may need to convey what he knows with more clarity in the future. Based on this conversation, the interviewer asked him how he prepared for the exam.

1. I: To prepare for the midterm tell me a little about what you did to study
2. B: Umm I used the online, those were really helpful, the online past midterms yeah I went through those a couple times before I looked at the answers and then once I did I took a day or two off and then I re-went through them to see if I could like get the concepts
3. I: so you did the problems prior to looking at the answers?
4. B: yeah problems and then the answers and then I did the problems again later. I read through the chapters in the book a couple of times and I just looked at a few notes that I took during lecture but mostly it was the midterms and the book.
5. I: ok when you were doing the problems did you work by yourself or did you have anybody you studied with
6. B: no it was pretty much all by myself
7. I: and you said you did the problems before looking at answer key
8. B: yes

21. I: and so seeing how you did on the exam now and knowing how you studied what are the things that you think really helped you the most while you were studying, like oh that was really a good thing to do
22. B: umm the practice midterms were probably the most helpful thing. Yeah those and then having the solutions too so after you've done them a couple of times I like being able to check and see what's (shrugs)

Student B readily describes a resource he labels as really helpful to him -- past midterms posted online. In line 2, he states: "I went through those a couple times before I looked at the answers". This reference to evaluation of reviewing past exams as a helpful resource is repeated in line 22. He reports trying the problems on his own before referencing the answer keys in line 4 "yeah problems and then the answers and then I did the problems again later...". This repeated description of doing past exam problems is interpreted to exemplify a level 2 use of resources because he reports attempting the problems on his own and yet still appears to confine himself to the given problem. He does not provide any evidence to indicate further behavior of evaluation on how this problem could be varied or of evaluation on what other types of questions could be asked to test similar concepts.

He does not include in his description any indication of an attempt to think past the given problems or to hypothesize other possible situations which may have similar solutions. In line 6, student B states that he works alone in this process. While this appears to imply a more personal engagement with the problems and possibly actively working through them, this does not describe any evaluation of other solution paths or confirm understanding of the underlying process by engaging in conversation with anyone about the problem.

9. I: and did you go to any review sessions
10. B: no I didn't I actually umm I wasn't aware that there, well I was aware that there was one but I thought it was later in the day
11. I: ok and did you go to any office hours?
12. B: umm I've been to my GSI's office hours but not to the professors
13. I: and are they helpful?
14. B: yeah they are actually, I like the way the GSI's office hours 'cause he clears it up, and puts it in more, even the discussions as well, makes it more comprehendible, easier ways
15. I: and did you go to the SLC mock midterm or any of those things?
16. B: no

Student B does not appear to be seeking out many opportunities to learn from his peers or GSI. Already stating that he works alone when solving problems, he continues this theme when asked about review sessions or other group study. In line 14 he describes his impression when attending his GSI's office hours: "I like the way the GSI's office hours 'cause he clears it up, and puts it in more, even the discussions as well, makes it more comprehendible, easier ways". This implied focus on how the material is made "more comprehendible" is taken to indicate his desire to have the information explained to him. He does not appear to evaluate the information being told to him or to challenge what is being told to him. He appears to enjoy that it has been broken down into "easier ways" for him to understand, possibly so he does not have to struggle to understand it.

17. I: you said you looked back at the book
18. B: yeah a few times
19. I: when you were looking back at the book were you focusing more on re-reading or focusing more on doing more problems or what
20. B: focusing on trying to just like reading about concepts that I had a little trouble with 'cause like I knew the ones I had down so I just pushed those to the side and then I read the ones that I had problems with

When discussing his use of the textbook in the course, his focus appears to be reading the text for specific ideas or concepts to be explained to him. In line 20 he describes reading the text "...trying to just like reading about concepts that I had a little trouble with 'cause like I knew the ones I had down so I just pushed those to the side and then I read the ones that I had problems with". This description appears to indicate an intention and a motive in reading. More than a level 1 use of resources, student B describes a purpose in his use of the text. However, he appears to rely on the text to provide him a complete understanding of the concept. He does not indicate any attempt to synthesize this information and translate it into his own words. This description portrays what is characterized as a passive nature in learning concepts. He describes looking to the text to explain the ideas to him, which is similar to how he describes the purpose of the GSI in office hours.

*Explanation of boiling points and the possible correlation with use of resources for student B*

Student B appears to rely on given facts and macroscopic level observables or references when explaining his thinking about the exam question on boiling points. He does not appear to easily move to describing the phenomena at the atomic level. This correlates with his described level 2 use of resources, wherein he is dependent on external sources for explanations of concepts. While he describes connections between ideas, he makes no reference to a self-generated atomic level "picture". Instead, these explanations appear to be generated through ideas that are adopted without any evidence of evaluation concerning their accuracy or robustness.

Prompted by the interviewer to explain his answer to item 19 of his exam, student B recalls his thought-process and explores his understanding of boiling points in the following excerpt:

23. B: [reads problem out load] So first when I saw this $CH_4O$ and $CH_2O$ I kind of just like started picturing the lewis dot structures to kind of get, that's how I check out the polarity and then I decided to draw them up here and then this one had a, seemed like it had more of a, more of a pull, and it has like, I look at the type of bonds and stuff this one can hydrogen bond and this one can't 'cause its just hydrogen and carbon so I started like noticing all these factors how this ones got those stronger bonds and then I just I remembered that the stronger the bonds the more energy it takes to break which makes higher boiling point and so…
24. I: with hydrogen bonding are you actually breaking a physical bond?
25. B: ummm no its not its ahhh its like when an electron transfers and then this becomes a positive proton and then positive and negative charge attract that's why its strongest ….I'm pretty sure…and then ummm … I noticed this one has hydrogen bonds which are some of the strongest and this one didn't so I just figured that this would have a higher boiling point

Student B initially describes the facts he used to determine his original answer. He states in line 23, "then I just I remembered that the stronger the bonds the more energy it takes to break which makes higher boiling point and so…". He continues in line 25 with "...I noticed this one has hydrogen bonds which are some of the strongest and this one didn't so I just figured that this would have a higher boiling point". This statement of definitional facts appear to be the basis of his reasoning: stronger bonds result in higher boiling points, and hydrogen bonds are some of the strongest bonds,. Student B appears to move beyond memorized facts when he describes picturing the structures of the molecules, "...I kinda just like started picturing the lewis dot structures to kinda get, that's how I check out the polarity and then I decided to draw them up here..." (line 23). This inclusion of self-generated structural drawings and descriptions of related facts with the generated structures in his explanation is interpreted to demonstrate his ability to connect related ideas. Inclusion of how the ideas he has learned can be used to determine the answer correlates with a level 2 use of resources. He identifies what ideas are related to a specific topic and ties them together at least on a macroscopic level or without extensive evaluation of the connecting theory. Student B appears to have a rehearsed set of steps involving visualization of the molecules and applies facts to explain links between molecule characteristics and observed phenomena. Few alternate explanations are included in his description. He appears to rely on a more rehearsed path of applicable facts for the given topic.

26. I: and can you tell me a little more about how that by having those strong bonds relates to the boiling point?
27. B: ok…ummm…. Like stronger bonds, like sometimes when I think about something I like do bonds like this (holds hands together pulling them apart against curled fingers) the more energy there is in the bonds the more it takes to break them apart and so like I picture these ones are stronger bonds so it takes a lot more energy which can be like boiling point you have to supply more energy in order for it to boil and this one they are kinda weaker bonds so they can break apart easy because they do not need as much energy in order to separate them
28. I: So what's happening when something really.. like when we say it "boils"..whats really happening?
29. B: Its just turning from a liquid to a gas and it doesn't have to be heating but that's the way that I think of, its easy, but it can be like when the vapor pressure isn't equal to the ..ummm I don't even remember ummm …. the pressure of the liquid

In line 27, student B expands on why bond strength relates to boiling point. Student B states, "...the more energy there is in the bonds the more it takes to break them apart and so like I picture these ones are stronger bonds so it takes a lot more energy which can be like boiling point you have to supply more energy in order for it to boil and this one they are kinda weaker bonds so they can break apart easy because they do not need as much energy in order to separate them". Student B never appears to convey a clear atomic level picture of what is happening when something boils. He generally makes macroscopic observations such as "It's just turning from a liquid to a gas..." in line 29.

30. I: so when you think about like in this case heating what's really happening to actually make them boil?
31. B: umm well it heats up the individual molecules and in a liquid they are kinda connected but they are not free like a gas and as they get more energy they start to move faster and like vibrate faster and then eventually they get enough energy when they can break apart into the gas and then they just start bouncing all around (moves hands around to show gas molecules moving freely).
32. I: do they break apart as if breaking something physical or do they just…
33. B: ahhh its just a physical change 'cause its not altering the chemical structure its just breaking apart molecules… so its just physical. Anything from like freezing, boiling, melting, that's all physical changes, that doesn't affect the chemical structure

Unlike student A, student B appears to begin to try and visualize the phenomena. This is demonstrated in line 31 when he is pushed by the interviewer to describe boiling in even more detail "well it heats up the individual molecules and in a liquid they are kinda connected but they are not free like a gas and as they get more energy they start to move faster and like vibrate faster and then eventually they get enough energy when they can break apart into the gas and then they just start bouncing all around". Despite his earlier description including an atomic level model, he later appears to move back to a more general macroscopic phase description of "...anything from like freezing, boiling, melting..." in line 33.

Student B's description does not include a clear, self-generated, atomic level model explanation. This may be correlated with his reliance on external sources for explanations. Line 31 appears to describe his attempt at visualizing the atomic level. When pushed to explain further he quickly references facts (line 33) rather than discuss how to refine his description to explain the phenomena. He is possibly brought back to more macroscopic descriptions or reasoning of learned facts due to his lack of ownership in learning. He does not appear to demonstrate a position of authority for his own visualization to explain ideas. Student B appears to confine his role to recognizing when to apply the given ideas, and uses his visualization as supplementary to given facts. He makes no reference to allowing himself the authority to evaluate the information presented by others. His description is interpreted to imply a belief that he is to apply the given ideas, but not evaluate them or translate them into his own words or into his atomic level visualization. His described behavior correlates with a level 2 use of resources.

*Use of resources shift: moving from a 2 to a 3 over the semester*

Over the semester student B makes a transition from being characterized as a level 2, procedural learner, to a level 3, critical thinker in his use of resources. He describes his approach developing over the semester, which is characterized as a system where he evaluates his understanding though his ability to answer questions. He describes in line 37, "...first I take a practice midterm online and then I see which topics I'm having trouble with, I look those up, like I look through all the lectures to find those and then I look it up in the book, then I take the second midterm, like the second practice midterm, and then once I have taken that like I just skim over all the lecture slides again and then I take the midterm from this year again and see how I do...".

He further articulates his new approach when describing learning from peers and the textbook in line 47, "...I try to make sense out of everything in lecture instead of like ok I don't understand this and going back and checking at it but like in lecture I ask like people around me, 'cause a lot of times my friends go with me, and like so I ask them so we talk about it and try and make sense of it so that's like the first step. And then just in studying like for example last night I was studying like buffers 'cause those are still a little bit confusing, but like there is this section in the book its like a paragraph and I read it just like 10, 20 times just to make sense of it, and it did, it works." This described focus on making sense out of everything seems to correlate with his transition. His behavior appears to transition from describing passively accepting ideas presented to evaluating these ideas and translating them into his own words. He no longer appears satisfied with simply knowing how to answer a question. Rather, he now describes taking the extra step of evaluating his understanding to ensure he is using an accepted process to find the answer.

34. I: What was the most significant changes you made to your study habits over the semester?
35. B: The first midterm I was kinda like ok you know chemistry it can't be that difficult so I studied a little bit but I wasn't as much but now like this whole week I devoted for this chem. final studying

and doing a different theme every day like Friday I'll do all of them and then Saturday after my first final I'll review them some more so like a lot more in depth and like effective studying too.

36. I: define for me what more effective is
37. B: well like before I would just do the practice midterms and like look at some of the book but now like I have this whole system down, I don't know how I came up with it, but like, first I take a practice midterm online and then I see which topics I'm having trouble with, I look those up, like I look through all the lectures to find those and then I look it up in the book, then I take the second midterm, like the second practice midterm, and then once I have taken that like I just skim over all the lecture slides again and then I take the midterm from this year again and see how I do. That's actually improved my scores, like I wish I would have done this before all the midterms 'cause I would have gotten a little better scores..but….
38. I: do you feel like your focus in what your trying to learn is any different from the beginning of the year?
39. B: I don't know if the focus is any different I just think the way I am doing it is different
40. I: do you feel like you are memorizing a lot in this course?
41. B: nope not really like the only thing feel like I am memorizing is the basic trends in the periodic table but then that can be used to like, like I can tie that into everything else so it's not a lot of memorizing just…well like a few things like how to draw this stuff (points at lewis structures) and basics but its not a whole lot of memorization
42. I: do you feel like that was a surprise to you, like when you came in did you feel like chemistry was a lot of memorizing?
43. B: uhh not really like I've kinda known that a lot of things you can tie into each other like a lot of sciences and even math and stuff like that you can like tie in a lot but I didn't know I didn't know you could tie in so much like relate everything in chemistry the way you could
44. I: When would you say you made these changes?
45. B: umm I would probably say after the second, well I made some changes after the second midterm and then a few after the third and then like after this fourth one 'cause I calculated all the stuff and what I need to get a B in this class so like all that so that has influenced me to study more.

This topic of changes to study habits resurfaced when discussing his exam scores over the semester:

46. I: do you feel like certain things in your studying were really key to making those improvements?
47. B: I would say one thing not in studying but just in lecture like trying to piece everything together more, like I try to make sense out of everything in lecture instead of like ok I don't understand this and going back and checking at it but like in lecture I ask like people around me, 'cause a lot of times my friends go with me, and like so I ask them so we talk about it and try and make sense of it so that's like the first step. And then just in studying like for example last night I was studying like buffers 'cause those are still a little bit confusing, but like there is this section in the book its like a paragraph and I read it just like 10, 20 times just to make sense of it, and it did, it works

Student B exemplifies a level 2 use of resources at the beginning of the semester. He relies on external sources for explanations. He appears to make partial attempts to generate an atomic level visualization, but quickly falls back on externally generated explanations. This is mirrored in his understanding of boiling points. At the end of the semester, student B makes a transition to evaluating the ideas presented to him on topics and translating them into his own words. He begins to give himself authority to evaluate his own understanding. This transition is described as happening gradually. The motivating factor attributed to this change is his desire to develop a more complete understanding of topics in the course.

**Student C, Level 3 to 4**

*Initial use of resources analysis for student C*

Student C was characterized as taking a much more active role in his learning. He appears to view himself as having the authority to evaluate the information presented and question its accuracy. This demonstrates a level of confidence in his role as a learner. Student C describes evaluating explanations on a topic from various sources to generate his own understanding of the topic. His behavior of translating ideas into his own words appears to correlate with allowing himself the authority to evaluate ideas before incorporating them into his understanding.

After discussing his previous experiences with chemistry, the interviewer asked student C to describe his approach to studying for the first exam in the course.

1. I: In preparing for the midterm, tell me about how you studied for it.
2. C: Well first of all before I go to lecture I tend to read the assigned reading so I know what the professor is talking about. After lecture I usually go back and read it over again if there is anything I need to clarify. And then I do some practice problems out of the back of each section. Then when it comes to the week of midterms or the week before I start looking at the webcasts over again and then start my little things and stuff. I am not the type of student to really cram, so I start early.
3. I: Just to clarify, you said you took the past exams earlier, when taking them what did you do?
4. C: I had the answer key but I wasn't looking at it. But it was open as a file. I took it pretty informally I was sitting with a friend and looking at the computer screen and we went through and had kinda a discussion about it.

11. I: out of all the things you did for the exam and how the exam went, what do think was the most helpful thing that you did?
12. C: I think definitely the most helpful in terms of doing well on the midterm was the practice midterms

Initially he describes using the text to gain insight into what the lecture is about and referencing the text after the lecture to help clarify ideas for himself. From this description he appears to have less reliance on external sources for understanding. His use of the text is characterized as reference, which helps to build his own understanding. In line 2 student C states "first of all before I go to lecture I tend to read the assigned reading so I know what the professor is talking about. After lecture I usually go back and read it over again if there is anything I need to clarify. And then I do some practice problems out of the back of each section...". Inclusion of the additional step of testing his understanding through problem solving correlates with a level 3 use of resources (critical thinker). A critical thinker not only describes attempts to understand the ideas but includes reference to testing his ability to apply them in explaining new situations.

Unlike descriptions of independently working problems from the textbook, student C admits, in talking about past exams, not trying them on his own. Instead he describes discussing them with a peer. In line 4 this peer interaction is described as "...I was sitting with a friend and looking at the computer screen and we went through and had kinda a discussion about it". This is interpreted to indicate a dialogue back and forth when reviewing these past exam questions. This type of dialogue suggests evaluation of each other's ideas and explanations towards the problems. The inclusion of the described step of evaluating each others ideas correlates with a level 3 use of resource. This is further exemplified in line 6 where he describes his interactions with peers, "...I'll study by myself until it's the week of the test and then I will start shooting answers around with other people and getting different opinions and stuff".

5. I: And so you said you worked with a friend, would you say more of your studying was done with other people or by yourself?
6. C: By myself. I don't like to study in a group too much so I'll study by myself until it's the week of the test and then I will start shooting answers around with other people and getting different opinions and stuff.
7. I: Did you go to any of the review sessions? [student asked for clarification of GSI or whole class]
8. C: I did go to a couple of the Thursday ones. I went to the first one and later ones. I usually have things to do then so I can't make it every week.
9. I: Did you go to the SLC mock midterm?
10. C: yeah I did. It was pretty helpful I think

*Explanation of boiling points and the possible correlation with use of resources for student C*

Student C appears to include his self-generated atomic level model when he describes his thinking related to the exam question on boiling points. He gives reference to the ideas he has been presented on the topic and then would generate his own visualization incorporating the ideas. This appears to correlate with his level 3 use of resources. He appears to describe translating his understanding into his own words or atomic level model and evaluating this self-generated model for its limitations.

Prompted by the interviewer to explain his answer to item 19 of his exam, student C recalls his thought-process and explores his understanding of boiling points in the following excerpt:

13. C: well first of all I drew the lewis dot structure. I used the way they taught in the book, or some book, with summing up all the total electrons and then rationing them out basically. So I guess I got the right structure. Then the first step I took was thinking about why methanol had a higher boiling point and from what I learned this would either be due to intermolecular forces. So then thinking about why this one would have greater forces than that one.
14. I: why do you relate intermolecular forces with boiling?
15. C: Part of it is just from experience. I guess common sense, if you have a very sticky fluid or something that has a strong force holding it together its hard to have it move around. It's hard to have molecules flying off of it. So the common sense of it made good sense to me. Also in class and office hours the professor went through this particular type of problem and indicated that we should look for things such as dipole-dipole interactions, hydrogen bonding. So this was not a totally new problem to me. I kinda knew where to go.

Student C appears to include his own understanding in line 15 by referencing ideas that were presented on the topic along with related examples that had been shown. He states, "...I guess common sense, if you have a very sticky fluid or something that has a strong force holding it together its hard to have it move around. It's hard to have molecules flying off of it. So the common sense of it made good sense to me....". When he describes reference to use of others ideas, "...Also in class and office hours the professor went through this particular type of problem..." (line 15), he includes a description demonstrating his ability to evaluate the given ideas used in the explanation he is giving,

"...So the common sense of it made good sense to me..." (line 15). All these evaluation of ideas and self-generated analogy correlates to his level 3 use of resources.

16. I: So what was the key force you found for methanol?
17. C: Hydrogen bonding.
18. I: How does hydrogen bonding relate to boiling?
19. C: Well it is, the way I think about it is that it is one of the strongest, wait I don't know if its THE strongest, but one of the stronger intermolecular attractions in that oxygen has the two lone pairs and they attract a hydrogen each so its like a network sort of, of attraction and stuff. I just feel like it would be strong holding the water together or sorry not water but like hydrogens in water. Also I learned in bio that one of the special things about water is that it hydrogen bonds and so it has a lot of properties and I kinda extended those to methanol. I figured that since water has a high boiling point then methanol probably would too.

Not appearing to limit himself to the course resources, he describes an ability to recognize links with other science courses "...I learned in bio that one of the special things about water is that it hydrogen bonds and so it has a lot of properties and I kinda extended those to methanol..." (line 19).

20. I: So what happens when something "boils"?
21. C: Well the bubbles that you see coming out are like just water molecules that have broken the hydrogen bonds and are (waves hands around) pushing against the atmospheric pressure and they come out, or that's how I think about it.
22. I: So what do they actually break or how do they break?
23. C: Ummm they don't break anything within the molecule they break the intermolecular forces so I guess it would be breaking the hydrogen bond. I guess when you heat it you exert the energy needed to, like they start shaking (shakes hands around) is how I picture it, they start shaking against each other and eventually they just break apart since they move around too much.
24. I: So if you look at a little puddle of methanol and could zoom in and "see" just 10 molecules, what would you "see" happening? Describe it to me.
25. C: Like I said earlier they would start shaking and I imagine them being connected through the hydrogen bonding. And then eventually one of them would just start shaking so fast that it can't be held there anymore and it starts like going to the gas phase. I remember one of the preclass assignments, also it was in lecture, a picture of molecular workbench or whatever the program is, and there were little molecules flying around bouncing around off the walls and that's kinda what I see going on in the transition between the liquid and the gas phase.

Within his description, reference is made to imagining phenomena at the atomic level through the following statements, "...they start shaking is how I picture it..." (line 23) and "...I imagine them being connected through the hydrogen bonding..." (line 25). These statements are interpreted to suggest self-generation of atomic level models to "see" what is happening. Student C is characterized as going past the macroscopic, observable, ideas and attempting to imagine how the atoms are interacting.

26. I: And what do you picture the hydrogen bond to really be?
27. C: I guess my picture is an over-simplification. It's just a line connecting two atoms. I'm pretty sure its not like that in actuality. I have actually been thinking about that a lot like how bonds at a physical level, how they form. But I am not too sure about that. I think I will take some physical chem courses and try to figure that out. But at this point its just the very rudimentary model for it.
28. I: So from what you view in your head is a hydrogen bond like a physical connection or is it ......
29. C: I wouldn't really describe it as a physical connection. Ummm I think its just the mutual attractions for the electrons the two atoms have. But in my model it is literally just a line

connecting them so there is some, something like, I have to connect my model with the actuality. Remind myself that what I think about is not entirely correct.

30. I: Are their still things you don't have a clear picture in your head about for these things, like this bonding?
31. C: Their are a lot of things that I don't feel totally comfortable at the very fundamental level with. But I think that's kinda expected ‘cause its an intro to general chem course and we aren't suppose to go deep deep into this. Yeah just like the basic things, how bonds form, what does electronegativity really means, you know things like that. The very fundamental level, and I definitely feel an urge to learn but probably not at this point. For now I guess I'll move forward and I can come back and solidify those concepts.

Not only does student C appear to generate his own atomic level models to explain his ideas, he also describes realizing the limitations of these models. In line 27 he states, "I guess my picture is an over-simplification. It's just a line connecting two atoms. I'm pretty sure its not like that in actuality...". This is considered to further exemplify his continual evaluation of not only the information presented but his own explanations as well. This ability to describe awareness of his capacity to create logical explanations and evaluation of his own understanding correlates with a level 3 use of resources.

*Use of resources shift: moving from a 3 to a 4 over the semester*

Characterized in his use of resources as a level 3, critical thinker, student C transforms into a level 4 use of resources over the semester. Not initially appearing to recognize major changes over the semester, he later gives reference to peer-motivated changes stemming from early in the semester, "...I definitely made a transition from high school that I actually read the book and I check for understanding of key concepts" (line 33). His description of application to everyday life and observed phenomena characterizes the main shift in his use of resources. This is described in line 35 "Once I look in the book I look around and think can I explain this with this. Can I explain what is happening here with what I know is learned...". While Student C does not report to perceive any major changes to his use of resources over the semester he reflects in line 37, "...Then I realized very early, after the first midterm, instead to do a little more" and in line 39, "...Little things like yes I need to do more problems and focus less on whatever aspect of this and that". This description of a shift to include application of the concepts to everyday life is considered more than trivial. This correlates to the difference described between a student using resources at a level 4 and a student using resources at a level 3; the latter not realizing the larger application of the material.

32. I: What are the most significant changes you have made in your study habits this semester?
33. C: I think I haven't changed too much since after coming to college. I definitely made a transition from high school that I actually read the book and I check for understanding of key concepts.
34. I: How do you check?
35. C: Once I look in the book I look around and think can I explain this with this. Can I explain what is happening here with what I know is learned, and the other is I read a lot of problems. Various types of problems from the book, from other sources, and I think what is important about that is that it tests for your ability to do things, to apply the concepts, and in situations that you have never seen before and I think that is something outside of chem 1A. I like the seemingly random things that I come across, but I think its a good system it forces people to apply the knowledge, the very bare knowledge that they have and explain things and the midterms are pretty rewarding and forgiving in that they accept a variety of answers and possible explanations. Also the partial credit.

36. I: You said you made a transition coming from high school into college, when did that happen and why?
37. C: That happened some time during the summer. I got in contact with a lot of my friends in college and they said if you go in and take this high school attitude you will find your first semester really difficult. So I convinced myself to make these little changes to my habits and I was really lucky in that regard. Then I realized very early, after the first midterm, instead to do a little more.
38. I: After the first midterm did you make any further realizations or changes?
39. C: Not anything too major. Little things like yes I need to do more problems and focus less on whatever aspect of this and that.

Student C exemplifies a level 3 behavior at the beginning of the semester. His reference to evaluating ideas is critical. Student C takes the additional step to evaluate ideas that are presented to him. He also translates these ideas into his own words or self-generated model. This exemplifies how level 3 students take on a position of authority and allow themselves to evaluate ideas for accuracy and then create their own understanding. His transition over the semester to a level 4 use of resources is grounded in his inclusion of everyday life applications. In his understanding of the concept Student C begins to include application of the concepts to everyday phenomena. This exemplifies a level 4 use of resources. Similar to student A, this transition appears to be peer motivated. Student C describes making this change based on peer advice.

**Summary**

These case studies answer the fourth research question "Does student use of resources correlate with understanding of chemistry concepts or development of scientific thinking in introductory chemistry?" These three case studies exemplify student use of resources at levels 1, 2 and 3. They help explain correlations between the behaviors that students exhibit in their use of resources and understanding of the course material. Student explanations concerning the exam question on boiling points correlate with their respective use of resources levels from the Use of Resources Framework (Figure 27).

Student A exemplifies a level 1 use of resource which is characterized as passive reliance on external sources for information and answers. The following behaviors are used to support this claim. He appears to demonstrate a belief in learning as one-directional, wherein a source of knowledge conveys information to him the student. His description of a passive approach to learning correlates with what appears to be his passive attempt to connect recalled information. He does not mention any attempt at including self-generated explanations. When exploring his understanding of boiling points his description appears to focus on restatement of memorized facts. He is interpreted as accepting facts given to him, while indicating no sign of evaluation.

Student B exemplifies a level 2 use of resources. Compared to Student A, Student B demonstrates a less passive use of resources. He appears to be taking the added step of assessing for understanding by working out problems (student B line 2-4). Student B, like student A, still relies on external sources for ideas used to describe concepts. He does not show confidence in his own ability to evaluate these ideas for accuracy. Characterized as moving beyond memorized facts, student B describes picturing the structures of the molecules when explaining boiling points (student B line 23). The inclusion of self-generated structural drawings and connection of facts with the generated structures in his description manifests his ability to connect related ideas. Exemplary of his level 2 use of resources is this apparent awareness that ideas learned can be used to determine the answer, without including mention of evaluation towards these connections.

Student C exemplifies a level 3 use of resources. Unlike Students A and B, Student C appears to take a much more active role in his learning. He describes his role as a learner with confidence. He includes in his description of his role as a student the authority to evaluate information presented and to question its accuracy. In his descriptions, Student C evaluates multiple explanations on a topic and translates them into his own words to develop his understanding of the topic. This level 3 use of resources is correlated with his explanation of boiling points. His explanation appears to include use of a self-generated atomic level model visualization. He also added a reference to the limitations of this self-generated model. Inclusion of evaluating ideas presented, along with his own ideas, for accuracy is exemplary of a level 3 use of resources.

All three students shifted their levels of use of resources. Over the semester, student A shifted from a level 1 to a level 2 use of resources. This change over the semester is attributed to peer influence, as he follows the advice of another student. The main changes identified in his use of resources over the semester are his increased ownership of knowledge, and his beginning awareness of the need to do more than just memorize facts. He still displays a reliance on external sources for learning at the end of the semester, but begins to appear more independent.

Student B's transformation from a level 2 to a level 3 use of resources is interpreted as rooted in a growing dissatisfaction with simply knowing how to answer a question. This discontent appears to motivate him to take the extra step of evaluating his understanding. His mention of conversing with other students to "make sense of it" demonstrates a shift in his behavior allowing himself to become a source of authority to evaluate chemistry ideas. The shift from accepting presented ideas to having authority over presented ideas correlates with the difference between student B at a level 2 use of resources and student B at a level 3 use of resources.

Over the semester student C evolves from a level 3 into a level 4 use of resources. This transition appears to be motivated by his peers' suggestions to be more independent and to take ownership of his learning. His largest change is characterized by his description of making links to the real world. This apparent shift to include application of the concepts to everyday life is more than trivial. This correlates with the difference described between a student at a level 3 use of resources, who does not realize the larger application for the material, and a student at level 4 use of resources.

These case studies identified correlations between student's described understanding of boiling points and student's use of resource level. These correlations provide support for the idea that higher level behaviors will prove more successful in the development of scientific thinking. Based on these findings, students may require shifting their use of resources to a higher level in order to gain a more complete understanding. These case studies explore the shifts made by these three students in their use of resources. The analysis of these shifts provide insights into possible paths students may take to become more successful as well as the possible motivations to encourage these paths. Future interventions to encourage students to use course resources more effectively can be informed by this understanding of possible motivators for, and pathways to, shifting their use of resources to a higher level. While these are only three case studies, they exemplify transitions that show evidence to increased student learning. These transitions are considered to be the development students may need to make over the semester to increase their understanding of chemistry concepts.

# Chapter 9: Conclusion

The purpose of this dissertation research is to help understand why some students struggle while others succeed in introductory chemistry. Instructors at this university repeatedly find capable students failing to achieve success in the introductory chemistry course. While all students have the ability to succeed in chemistry, this study investigates how their beliefs, perceptions, and behavior influence their level of success. Variables explored include student: (1) beliefs about learning science; (2) beliefs in their academic ability; (3) perceptions of the classroom environment; (4) perceptions of external support; and (5) behavior in use of resources.

Of these dimensions, student beliefs in their academic ability had the largest influence on student success, as indicated by exam scores. Moreover, the relationship between beliefs in ability and success is mediated by student use of resources. The explanation for this mediating effect is found in part through the case studies. Case study analysis identified correlations between students' use of resource levels and students' described understanding of boiling points. A more complete understanding of boiling points was taken to indicate a higher level of success. These correlations provide support to the idea that higher level behaviors will prove more successful in the development of scientific thinking. Where students place authority to evaluate information is influential to success. Students who use resources at higher levels (level 3 and level 4) place authority within themselves and students who use resources at lower levels (level 1 or level 2) place authority externally. This placement of authority appears to be linked with students' confidence or beliefs in their ability. Increased belief in their ability will provide students the confidence to use resources at a higher level, and by moving to a higher level use of resources, will also increase their success in the course.

This mediating role of use of resources suggests a potential for interventions aimed at modifying student behavior towards use of resources. It is recommended to instructors to encourage and support students towards behaviors that reflect a level 3, critical thinker, on the Use of Resources Framework for Chemistry. For most students, this is a reasonable shift within the scope of the course and can happen within the semester timeframe. The shift to a level 4 use of resources, researcher, may be too large a transition for most students to successfully accomplish within one semester.

Based on the number of students moving from use of resources levels 1 and 2 into levels 2 and 3 respectively (24 of the 61 students, or 39%), it is suggested that the current course is beginning to accomplish this goal. The modified curriculum used in this course may have modeled effective behaviors which were translated by students for use when studying outside the classroom. Continual reference to familiar context throughout each unit may have cued students to link ideas from the course to explain everyday phenomena. One example of this link with everyday phenomena is characterized by the following quote from one student interview, "...I remember at the beginning of the semester the professor said that he wants us to think about chemistry wherever we go and sometimes if I am just like sitting there, I will try and explain stuff with chemistry ... I can think of everything as a chemical process right now so that has opened my mind ..."

Peer interactions in class may have encouraged students to continue peer interactions outside the classroom. In reference to these kind of interactions one student reported during an interview "...when I read the book I think oh I know this but then when I talk with other people and they show me different ways of doing it or different ways of viewing it to solve it I am thinking ok so I know just part of this and its better if I communicate with others people..". Another student reported making the realization in class that "...if I can't explain it to someone else I am not understanding it myself...".

Exam items asking students to apply the ideas from the course in novel situations may have also had an impact. Multiple students mention that the exam questions pushed them to understand the material at a deeper level and to develop the ability to apply things they are learning in new situations during the exam. This is cited repeatedly during interviews as motivating them to change their approach to learning when studying for this course. One student during an interview said "I think this class sort of challenges us to think beyond just the concepts that are presented and ...to keep asking questions and wonder why this is happening on a very microscopic level. What is happening, what are the interactions, why does this happen, and then sort of trying to translate that into why this result will be observed". These findings will be used to inform the design of embedded curricular interventions. The interventions will aim to promote effective use of the course resources which, in turn, will lead to increased development of scientific thinking.

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## Appendix A: Complete lists of survey items with factoring results

Complete list of four item Likert scale items administered as part of the Fall 2009 survey version (Response choices: strongly disagree, somewhat disagree, somewhat agree, strongly agree).

| Factor Grouping | Item Sequence | Item |
|---|---|---|
| Ability | 2 | I do well in math and science courses |
| | 6 | Chemistry material does not come naturally to me |
| | 7 | I have to work much harder than my peers to do well |
| | 20 | I expect to get an A in this class |
| | 26 | I already have a good understanding of chemistry from previous courses I have taken |
| | 28 | I am not very good at Chemistry |
| | 32 | I can get an A in this class |
| BLS | 4 | |
| | 9 | I am more interested in learning chemistry than in the grade I earn |
| | 12 | Ultimately the only thing that really counts is your final grade |
| | 13 | I am only taking chemistry because it is required |
| | 17 | There is more than one correct way to think about concepts in chemistry |
| | 19 | Chemistry concepts are not that relevant to the real world |
| | 25 | Chemistry does not always have one right answer to every problem |
| | 30 | I just need to do enough work to pass this class |
| | 33 | When learning chemistry, I focus more on understanding the underlying theory than memorizing facts |
| | | Science is not just facts to memorize independently, they relate to each other |
| | 36 | Science is just a lot of facts that you need to memorize |
| Support | 10 | My friends believe in me |
| | 21 | I do not have a great network of support |
| | 22 | Someone in my family is always there for me |
| | 24 | I do not have anyone to call when I am frustrated or overwhelmed with school |
| | 29 | I have people I can call for help when I have questions about chemistry |
| | 31 | My family understands the struggles of studying science in college |
| | 35 | My parents are proud that I am at UC Berkeley |
| No Grouping | 1 | I like studying chemistry because it is fact based |
| | 3 | I have friends in this class |
| | 5 | There are times, in high school or college, when I have asked my parents for help with my schoolwork |
| | 8 | Knowing math is the secret to success in a chemistry course |
| | 11 | To be successful at chemistry, hard work is much more important than inborn natural ability |
| | 14 | My parents do not care how well I do in school |
| | 15 | Science is about searching for the right answers |
| | 16 | I will let my family down if I do not do well in this course |
| | 18 | I will do more than the minimum amount of work I need to do, to get by |
| | 23 | I will work as hard as I need to get an A in this class |
| | 27 | My parents encourage and push me to do well in school |
| | 34 | My friends understand the struggles of studying science in college |

Complete list of four item Likert scale items administered as part of the Fall 2010 survey version (Response choices: strongly disagree, somewhat disagree, somewhat agree, strongly agree).

| **Factor Grouping** | **Item Sequence** | **Item** |
|---|---|---|
| Ability | 1 | I do well in math and science courses |
| | 3 | I worry that I am not prepared for this class |
| | 5 | Understanding chemistry does not come naturally to me |
| | 6 | I have to work much harder than other students to do well |
| | 10 | I expect to get an A in this class |
| | 14 | Chemistry is one of my best subjects |
| | 16 | I rarely need help to solve Chemistry problems |
| | 20 | I do poorly on Chemistry tests |
| | 22 | I already have a good understanding of chemistry from previous courses I have taken |
| | 24 | I am not very good at chemistry |
| | 27 | I do not think I am capable of getting an A in this course |
| Support (Family) | 7 | My parents care more about what I learn than the grades I earn |
| | 8 | My friends believe in me |
| | 11 | My family understands the struggles of studying science in college |
| | 13 | My parents are proud that I am at UC Berkeley |
| | 19 | Someone in my family is always there for me |
| | 23 | My parents would prefer that I stay at home and look for a job |
| | 26 | My family encourages me and provides motivation when I doubt my abilities in science |
| | 28 | My parents support me in making my own choices about my college education |
| Support (School) | | I have friends in this class |
| | 2 | I do not have a great network of support |
| | 18 | I do not have anyone to call when I am frustrated or overwhelmed with |
| | 21 | school |
| | | I know people I can call for help when I have questions about |
| | 25 | chemistry |
| | 29 | It is difficult to find other students to study with in chemistry |
| Group 4 (Pressure) | 4 | My parents are insisting that I major in science or engineering |
| | 9 | My parents are sacrificing a lot to send me to Berkeley |
| | 15 | I will let my parents down if I do not do well in college |
| | 17 | My parents will be very upset if I do not get an A in chemistry |
| No Grouping | 12 | I do not share problems I encounter in my classes with my family |
| | 30 | My friends understand the struggles of studying science in college |

Complete list of five item Likert scale items administered as part of the Fall 2010 survey version (Response choices: almost never, seldom, sometimes, often, almost always).

| **Factor Grouping** | **Item Sequence** | **Item** |
|---|---|---|
| Based on WIHIC Equity Scale Items | | |
| Equity | 3 | The staff gives as much attention to my questions as to other students' questions |
| Equity | 6 | I get the same amount of help from the staff as do other students' |
| Equity | 9 | I have the same amount of say in this class as other students |
| Equity | 12 | I am treated the same as other students in this class |
| Equity | 14 | I receive the same encouragement from the staff as other students do |
| Equity | 17 | I get the same opportunity to contribute to class discussions as other students |
| Equity | 21 | My work receives as much praise as other students work |
| Equity | 24 | I get the same opportunity to answer questions as other students |
| Based on WIHIC Involvement Scale Items | | |
| Involvement | 2 | I discuss ideas in class |
| Involvement | 5 | I give my opinions during class discussions |
| Involvement | 11 | My ideas and suggestions are used during classroom discussions |
| Involvement | 18 | I explain my ideas to other students |
| | 15 | I ask someone on the staff questions |
| | 20 | Students discuss with me how to go about solving problems |
| | 23 | I am asked to explain how I solve problems |
| Staff Support | 8 | Someone on the staff asks me questions |
| Based on WIHIC Support Scale Items | | |
| Staff Support | 1 | Someone on the staff takes a personal interest in me |
| Staff Support | 4 | Someone on the staff goes out of his/her way to help me |
| Staff Support | 7 | Someone on the staff considers my feelings |
| Staff Support | 13 | Someone on the staff talks with me |
| Staff Support | 16 | Someone on the staff is interested in my problems |
| | 10 | Someone on the staff helps me when I have trouble with the work |
| | 19 | My GSI moves about the lab to talk with me |
| | 22 | The staff’s questions help me to understand |

Descriptive statistics of four item Likert scale items, listed by grouping, from Fall 2009

| **Fall 2009 Items** | **Survey 1** Mean (SD) | **Survey 2** Mean (SD) | **Survey 3** Mean (SD) |
|---|---|---|---|
| **Ability Items** | | | |
| I do well in math and science courses | 3.35 (0.64) | 3.17 (0.69) | 3.11 (0.69) |
| Chemistry material does not come naturally to me | 2.36 (0.83) | 2.26 (0.84) | 2.18 (0.86) |
| I have to work much harder than my peers to do well | 2.38 (0.87) | 2.15 (0.89) | 2.14 (0.85) |
| I expect to get an A in this class | 2.96 (0.77) | 2.46 (0.97) | 2.24 (1.00) |
| I already have a good understanding of chemistry from previous courses I have taken | 2.44 (0.94) | 2.14 (1.00) | 2.14 (0.96) |
| I am not very good at Chemistry | 2.53 (0.84) | 2.31 (0.92) | 2.28 (0.93) |
| I can get an A in this class | 3.29 (0.69) | 2.76 (0.96) | 2.46 (1.06) |
| **Composite Ability Variable** | 2.76 (0.56) | 2.47 (0.67) | 2.36 (0.67) |
| **Cronbach Alpha Ability Variable** | 0.83 | 0.86 | 0.86 |
| **Support Items** | | | |
| My friends believe in me | 3.35 (0.61) | 3.28 (0.65) | 3.32 (0.66) |
| I do not have a great network of support | 2.98 (0.80) | 3.05 (0.80) | 3.11 (0.81) |
| Someone in my family is always there for me | 3.39 (0.82) | 3.36 (0.79) | 3.37 (0.80) |
| I do not have anyone to call when I am frustrated or overwhelmed with school | 3.39 (0.80) | 3.27 (0.84) | 3.26 (0.82) |
| I have people I can call for help when I have questions about chemistry | 2.90 (0.79) | 2.83 (0.86) | 2.95 (0.83) |
| My family understands the struggles of studying science in college | 2.81 (0.90) | 2.81 (0.89) | 2.88 (0.88) |
| My parents are proud that I am at UC Berkeley | 3.63 (0.62) | 3.59 (0.63) | 3.54 (0.65) |
| **Composite Support Variable** | 3.21 (0.45) | 3.17 (0.47) | 3.21 (0.49) |
| **Cronbach Alpha Support Variable** | 0.67 | 0.71 | 0.75 |
| **Beliefs About Learning Science (BLS) Items** | | | |
| I am more interested in learning chemistry than in the grade I earn | 2.62 (0.71) | 2.52 (0.81) | 2.50 (0.81) |
| Ultimately the only thing that really counts is your final grade | 2.71 (0.80) | 2.52 (0.83) | 2.48 (0.81) |
| I am only taking chemistry because it is required | 2.60 (0.89) | 2.44 (0.94) | 2.37 (0.90) |
| There is more than one correct way to think about concepts in chemistry | 3.19 (0.65) | 3.20 (0.68) | 3.14 (0.73) |
| Chemistry concepts are not that relevant to the real world | 3.52 (0.64) | 3.46 (0.68) | 3.44 (0.76) |
| Chemistry does not always have one right answer to every problem | 3.05 (0.71) | 3.15 (0.71) | 3.13 (0.70) |
| I just need to do enough work to pass this class | 3.34 (0.71) | 3.30 (0.76) | 3.21 (0.85) |
| When learning chemistry, I focus more on understanding the underlying theory than memorizing facts | 3.03 (0.67) | 3.10 (0.68) | 3.16 (0.69) |

| | | | |
|---|---|---|---|
| Science is not just facts to memorize independently, they relate to each other | 3.58 (0.56) | 3.51 (0.60) | 3.42 (0.63) |
| Science is just a lot of facts that you need to memorize | 3.18 (0.77) | 3.25 (0.72) | 3.13 (0.77) |
| **Composite BLS Variable** | 3.08 (0.38) | 3.05 (0.42) | 3.00 (0.43) |
| **Cronbach Alpha BLS Variable** | 0.71 | 0.77 | 0.75 |

Descriptive statistics of four item Likert scale items, listed by grouping, from Fall 2010

| Fall 2010 Items | **Survey 1** Mean (SD) | **Survey 2** Mean (SD) | **Survey 3** Mean (SD) |
|---|---|---|---|
| **Ability Items** | | | |
| I do well in math and science courses | 3.32 (0.60) | 3.20 (0.73) | 3.15 (0.67) |
| I worry that I am not prepared for this class | 2.01 (0.86) | 2.00 (0.90) | 2.02 (0.83) |
| Understanding chemistry does not come naturally to me | 2.37 (0.83) | 2.23 (0.90) | 2.22 (0.87) |
| I have to work much harder than other students to do well | 2.34 (0.84) | 2.15 (0.91) | 2.15 (0.90) |
| I expect to get an A in this class | 2.91 (0.82) | 2.53 (0.99) | 2.33 (1.00) |
| Chemistry is one of my best subjects | 2.06 (0.88) | 1.94 (0.93) | 1.94 (0.93) |
| I rarely need help to solve Chemistry problems | 2.02 (0.75) | 1.89 (0.87) | 1.97 (0.82) |
| I do poorly on Chemistry tests | 2.73 (0.75) | 2.21 (0.90) | 2.19 (0.88) |
| I already have a good understanding of chemistry from previous courses I have taken | 2.29 (0.89) | 2.12 (0.96) | 2.09 (0.95) |
| I am not very good at chemistry | 2.50 (0.86) | 2.29 (0.94) | 2.27 (0.92) |
| I do not think I am capable of getting an A in this course | 3.06 (0.82) | 2.51 (1.00) | 2.46 (1.01) |
| **Composite Ability Variable** | 2.51 (0.58) | 2.28 (0.66) | 2.25 (0.64) |
| **Cronbachs Alpha Ability Variable** | 0.90 | 0.91 | 0.91 |
| **Support (Family) Items** | | | |
| My parents care more about what I learn than the grades I earn | 2.60 (0.88) | 2.72 (0.89) | 2.78 (0.87) |
| My friends believe in me | 3.45 (0.58) | 3.40 (0.60) | 3.43 (0.58) |
| My family understands the struggles of studying science in college | 2.89 (0.82) | 2.99 (0.84) | 3.03 (0.80) |
| My parents are proud that I am at UC Berkeley | 3.66 (0.57) | 3.62 (0.57) | 3.58 (0.63) |
| Someone in my family is always there for me | 3.46 (0.73) | 3.42 (0.77) | 3.42 (0.72) |
| My parents would prefer that I stay at home and look for a job | 3.81 (0.47) | 3.74 (0.60) | 3.72 (0.62) |
| My family encourages me and provides motivation when I doubt my abilities in science | 3.14 (0.73) | 3.05 (0.77) | 3.08 (0.74) |
| My parents support me in making my own choices about my college education | 3.34 (0.70) | 3.26 (0.71) | 3.25 (0.68) |
| **Composite Support Variable** | 3.29 (0.40) | 3.28 (0.43) | 3.29 (0.42) |
| **Cronbachs Alpha Support Variable** | 0.71 | 0.74 | 0.73 |
| **Support (School) Items** | | | |
| I have friends in this class | 3.21 (0.78) | 3.51 (0.68) | 3.51 (0.63) |
| I do not have a great network of support | 3.05 (0.80) | 3.16 (0.83) | 3.11 (0.85) |
| I do not have anyone to call when I am frustrated or overwhelmed with school | 3.39 (0.77) | 3.28 (0.77) | 3.25 (0.80) |
| I know people I can call for help when I have questions about chemistry | 3.02 (0.77) | 3.00 (0.76) | 3.05 (0.74) |
| It is difficult to find other students to study with in chemistry | 2.98 (0.78) | 2.94 (0.83) | 2.94 (0.84) |
| **Composite Support_school Variable** | 3.12 (0.52) | 3.18 (0.53) | 3.17 (0.55) |
| **Cronbachs Alpha Support_school Variable** | 0.69 | 0.72 | 0.74 |

Descriptive statistics of five item Likert scale items used to create Equity variable from Fall 2010

| **Fall 2010 Items** | **Survey 2** Mean (SD) | **Survey 3** Mean (SD) |
|---|---|---|
| The staff gives as much attention to my questions as to other students' questions | 3.76 (1.04 ) | 3.76 (0.98) |
| I get the same amount of help from the staff as do other students' | 3.51 (1.05) | 3.61 (1.05) |
| I have the same amount of say in this class as other students | 3.60 (1.08) | 3.64 (1.06) |
| I am treated the same as other students in this class | 4.16 (0.89) | 4.02 (0.96) |
| I receive the same encouragement from the staff as other students do | 3.80 (1.02) | 3.75 (1.01) |
| I get the same opportunity to contribute to class discussions as other students | 3.92 (1.00) | 3.89 (0.97) |
| My work receives as much praise as other students work | 3.41 (1.04) | 3.51 (1.02) |
| I get the same opportunity to answer questions as other students | 3.92 (0.95) | 3.85 (0.95) |
| **Composite Equity Variable** | 3.76 (0.77) | 3.75 (0.81) |
| **Cronbach Alpha Equity Variable** | 0.90 | 0.92 |

## Appendix B: Interview Protocols

Fall 2009 Interview 1 Protocol

| |
|---|
| **Q1:** How prepared do you feel you were for Chem 1A? |
| **Q2:** Before you took the midterm, as you went to the test, what grade did you expect to get on it?<br>During the exam how did you feel?<br>After the exam, as you walked out, how did you feel? |
| **Q3.** How did you feel about the grade you received?<br>Did you think it reflected your ability? |
| **Q4:** To prepare for this midterm …..<br>Did you work with others?<br>Did you work problems from the book or OWL (how did you use them?)<br>Did you take past exams?<br>Did you review the book, notes, etc.? (how did you use them?)<br>Did you go to the review sessions?<br>Did you go to office hours?<br>SLC mock midterm<br><br>What do you think helped you the most in studying for this exam? |
| **Q5:** Do you plan to make any changes in your study habits for the next midterm?<br>What changes?<br>Why? |
| **Q6:** On the survey you indicated that ________is possibly hindering your performance. Could you please explain this. (see factor #1 from survey) |

Fall 2009 Interview 2 Protocol

<table>
<tr><td colspan="2">Q1: Now that you have had a little more time in the course how do you feel about your preparation and ability now?<br><br>How do you think you compare with the other students in the class?</td></tr>
<tr><td colspan="2">Q2: Generally in the course have you changed your study habits at all?<br>Why did you make these changes?<br>How have these changes helped you?<br>Why weren't you doing this from the start?<br>Do you study with other students from the class? (How did you meet them? Was it hard?)<br>-if they say started going to OH or working with others probe what prompted them to do this, was it difficult, why now?</td></tr>
<tr><td colspan="2">Q3: Was your performance on this midterm what you had expected going into the exam?</td></tr>
<tr><td colspan="2">Q4. How did you feel about the grade you received on midterm 2?<br><br>Did you think it reflected your ability on this material?</td></tr>
<tr><td colspan="2">Q5: Tell me how you prepared for this midterm.<br><br>How was this different from how you prepared for the first midterm?<br>Why did you make these changes?<br>How did these changes affect your performance on the exam?<br>What do you think helped you the most in studying for this exam?<br><br>Do you plan to make any further changes in studying for midterm 3?</td></tr>
<tr><td>Q6: Last time we talked about the concerns you listed on the survey ____. How are these things going now?<br><br>Are there any other issues that have started to impact your performance?<br><br>Is there someone you talk to about struggles you are having with the class?<br><br>How do they help you? (if they focus on help with content redirect for more general struggles and concerns-who is your greatest supporter of being at Berkeley?</td><td>If no interesting factors or they did not seem to care about them last time ask….<br><br>How are things going in the course?<br><br>Is there someone you talk to about struggles you are having with the class?<br><br>How do they help you? (if they focus on help with content redirect for more general struggles and concerns-who is your greatest supporter of being at Berkeley?)</td></tr>
<tr><td colspan="2">Q7: Is there anything that is really helping you to do well in the class?</td></tr>
</table>

Fall 2009 Interview 3 Protocol

| |
|---|
| **Q1:** What is your reason for taking this class?<br><br>-What do you focus on when you are studying (what is your goal in learning chemistry)? |
| **Q2:** Tell me about your classmates and how do you feel about the class overall……<br><br>- How easy has it been to meet people and work with other classmates? |
| **Q3:** Looking back, how do you think your knowledge from previous science courses influenced you this semester?<br>What do you wish you had been stronger in at the start of the semester? |
| **Q4:** What are the most significant changes you have made in your study habits this semester?<br><br>-Why were they significant<br>-What prompted you to make these changes<br>-When did you make these changes<br>-Do you feel like you are memorizing a lot this semester |
| **Q5:** Was your performance in this class so far what you had expected going into the course? |
| **Q6:** What grade do you expect to get this semester?<br><br>-Are you satisfied with that grade? (if not satisfied – what could you have done better or what do you think caused this?)<br>-how are you feeling about the final? |
| **Q7:** I notice that your midterm scores have **__up/down/flat/fluctuating__**. What do you think caused this? |
| **Q8:** Describe to me what a "good" chem. 1A student looks like…..<br><br>-are you a "good" student<br>-If no-- How are you different from this? Why? So what type of student do you think you are? |
| **Q9:** Has this class changed how you think about chemistry at all?<br><br>-In what ways? |
| **Q10:** How has this class helped you to shape (or strengthen) your future goals or direction? |