IDENTIFYING THE RELATIONSHIP BETWEEN FEEDBACK PROVIDED IN COMPUTER-ASSISTED INSTRUCTIONAL MODULES, SCIENCE SELF-EFFICACY, AND ACADEMIC ACHIEVEMENT

by

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Determining the Relationship between Computer-Assisted Feedback, Self-Efficacy, and Academic Achievement

Thesis directed by Associate Professor Joanna Dunlap

ABSTRACT

Feedback has been identified as a key variable in developing academic self-efficacy. The types of feedback can vary from a traditional, objectivist approach that focuses on minimizing learner errors to a more constructivist approach, focusing on facilitating understanding. The influx of computer-based courses, whether online or through a series of computer-assisted instruction (CAI) modules require that the current research of effective feedback techniques in the classroom be extended to computer environments in order to impact their instructional design.. In this study, exposure to different types of feedback during a chemistry CAI module was studied in relation to science self-efficacy (SSE) and performance on an objective-driven assessment (ODA) of the chemistry concepts covered in the unit. The quantitative analysis consisted of two separate ANCOVAs on the dependent variables, using pretest as the covariate and group as the fixed factor. No significant differences were found for either variable between the three groups on adjusted posttest means for the ODA and SSE measures ($_{.95}F_{(2, 106)} = 1.311, p = 0.274$ and $_{.95}F_{(2, 106)} = 1.080$, $p = 0.344$, respectively). However, a mixed methods approach yielded valuable qualitative insights into why only one overall quantitative effect was observed. These findings are discussed in relation to the need to further refine the instruments and methods used in order to more fully explore the possibility that type of feedback might play a role in developing SSE, and consequently, improve academic performance in science. Future research building on this study may reveal significance that could impact instructional design practices for developing online and computer-based instruction.

This abstract accurately represents the content of the candidate's thesis. I recommend its publication.

Signed

Joanna Dunlap

DEDICATION PAGE

I would like to dedicate this dissertation to my husband. He tirelessly and lovingly supported me through three degrees spanning eleven consecutive years of attending college.

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CHAPTER 1

INTRODUCTION, OVERVIEW, AND REVIEW OF THE LITERATURE

Since the 1980s, the decrease in the percentage of college graduates with science, math, engineering, and technology (SMET) majors has fueled a number of educational initiatives directed at increasing these numbers (Seymour, 2002). These proposed changes focused not only on increasing the overall number of SMET degrees earned by undergraduate students in the United States but also on increasing the representation of women and minorities among the SMET graduates. Sims (1992) noted that the National Science Foundation and the National Institute of Health allocated over two-billion dollars towards increasing the participation of women and minorities in the sciences. These early programs had a positive effect on the number of women and minorities entering higher education with a SMET major declared. However, even with these deliberate interventions, the number of graduates from these programs continued to decline, regardless of gender or race. Over the next two decades, educational researchers continued to identify the underlying reasons for the observed attrition of SMET graduates.

Seymour (2002) outlined the various research endeavors undertaken in the 1990s that strove identify the reasons why so few high school graduates in the United States continued on to complete a SMET degree. These reasons ranged from a lack of quality SMET education, elementary through high school, to the traditional lecture approach of SMET education in undergraduate programs. When Bandura's (1986) social cognitive theory was applied to the problem, the construct of self-efficacy, or an individual's perception about her or his capability to complete a given task, highlighted the role that an individual's personal identity played in determining her or his likelihood to pursue a SMET major. Thus, many of the proposed solutions to this problem include both pedagogical and psychological recommendations for changes in the classroom to increase the number of students who choose to enter an undergraduate SMET program and continue on to graduate successfully (Seymour, 2002).

As a high school chemistry teacher, I have a personal interest in ensuring that my students receive a high quality education that leaves them feeling empowered to continue with their science education. I even would argue that it is my responsibility to keep open (or force open) this door to a future in science and that, if I fail, I am guilty of perpetuating the decades-old problem of disproportionately few SMET graduates from United States higher education institutions. Thus, throughout my career in the classroom, I have actively sought innovative ideas for increasing students' interest and understanding in and about chemistry. To this end, I use many of the best practices of science teaching recommended in Seymour's (2002) summary of the multitude of activities and methods designed to improve both the access to and the quality of SMET education. For example, I employ clearly stated learning objectives for each unit of study, and I use assessments that facilitate students engaging in their own learning. Additionally, my efforts to stay abreast of the best practices for teaching science have kept me on the cutting edge of educational technology, so I am constantly looking for new ways to integrate technology into learning and assessment processes.

Unfortunately, I continually have been unimpressed with the quality of computer-assisted instructional (CAI) materials available for my content area. The department where I teach recently reviewed many new textbooks from various publishers. The problem was that, while each textbook was marketed as having an *interactive CD-ROM* for the students, the quality and depth of the learning experiences available on these CDs were uninteresting and only moderately engaging. Notably deficient in these examples were learner-feedback prompts. In each software title, the program used feedback for multiple-choice questions that was limited to *correct* or *incorrect*. Occasionally, incorrect responses were followed by a page reference for students to use to determine the correct response. In addition, some programs explained the right answer after the learner selected correctly. This banal approach to feedback does not encourage learners to engage in higher-order thinking skills, even though chemistry is a highly complex subject with many interrelating concepts and ideas.

My experiences in the classroom have taught me that appropriate feedback is essential for establishing an engaging and successful learning environment. Further, as a teacher I believe that many learners need positive, specific, and constructive feedback to improve self-efficacy (i.e., gain confidence in their abilities as a chemistry student). These instincts and experiences combined to ignite my passion for understanding how to design better CAI so that learners received a more engaging experience, fueled by the type of feedback that is successful in face-to-face environments. Thus began my journey that led to this dissertation and the research surrounding my initial interests in feedback, self-efficacy, and CAI.

Conceptual Definitions

I based the following conceptual definitions on those proposed by prominent researchers' as they laid the foundation of knowledge for the constructs and ideas presented in this dissertation.

Computer Assisted Instruction (CAI)

Computer assisted instruction is defined as any computer-based learning application that supplements a classroom environment. These applications can be delivered via CD-ROM, the World Wide Web, or other electronic sources. Typically, learners interact with the computer alone without the assistance of a teacher to answer questions.

Feedback

Feedback is defined as information presented to the learner after any input with the purpose of shaping the perceptions of the learner (Sales, 1993). For example, when the learner chooses a response in a multiple-choice style question, the computer program automatically provides information to the learner that will somehow inform him or her of the correctness of her or his response for the purpose of helping the learner to better understand a particular problem or concept.

Social Cognitive Theory

Social cognitive theory is the theoretical framework initial proposed by Albert Bandura. This theory hypothesizes that achievement depends on how a person's behaviors, thoughts, beliefs, and environmental conditions interact with each other (Bandura, 2001b; Schunk & Pajares, 2001).

Self-Efficacy

Self-efficacy is a person's beliefs about her or his ability to successfully complete a task. These beliefs can impact how a person feels, thinks, motivate themselves, and behaves (Bandura, 1994).

Science Self-Efficacy (SSE)

Self-efficacy, or an individual's beliefs about his ability to successfully complete a task, is content-specific (Bandura, 1994; Bong, 1997). Thus, because this study was performed using science students, science self-efficacy is the specific construct of interest. Science self-efficacy is the specific set of beliefs that learners have regarding their perception of their abilities to successfully complete science-related tasks.

Background and Significance

The evolution classrooms to include more CAI materials raises many issues about what constitutes best practices of teaching in this environment (Torrisi & Davis, 2000). Modern textbooks are commonly marketed with attention to the type and quality of CAI ancillary materials, which can be Web-based or stand-alone applications running from a CD-ROM. However, this drive towards including more instruction that is computer-based tends to ignore many of the established best practices of face-to-face teaching in terms of the quality and quantity of feedback provided to learners during instruction (Papanastasiou, Zembylas, & Vrasidas, 2003; Steinweg, Williams, & Warren, 2006).

The full potential of CAI to offer individualized, engaging, and effective learning experiences is rarely realized, particularly in how feedback can be used to enhance the learning experiences and achievement outcomes. Multiple levels of feedback can be programmed into CAI to enhance learner understanding and performance, separated by increasing complexity, or how much and what type of information is contained in feedback messages. The simplest forms, knowledge of response (KOR) and knowledge of correct response (KCR), both emphasize the correct response and do not provide further information to the learner about why the response chosen is correct or incorrect. A slightly more complex form of feedback, often termed KCR+, combines both KOR and KCR with additional elaborative information on why the correct answer is appropriate. Some KCR+ strategies also provide information about why a chosen answer is incorrect. All three of these feedback levels are designed primarily to reinforce the correct answer and do not necessarily challenge the learner to think independently to generate meaning and understanding.

Because feedback in CAI is often limited to KOR, KCR, and KCR+, the applications using these feedback styles do not directly facilitate how learners increase their knowledge and understanding from the feedback provided. Consequently, it is easy for learners to become disengaged. More complex forms of feedback may include (a) topic contingent (TC), containing KCR and topic-specific elaborative feedback; and (b) response contingent (RC), containing KCR and item-specific elaborative feedback (Jang, Kim, & Baek, 2001). These levels of feedback a form of coaching that requires more learner participation to process the feedback mindfully to increase understanding instead of simply reinforcing the correct answer (Jonassen, 1991).

Another factor that often contributes to the perception that CAI is uninteresting and boring is the removal of a teacher. In traditional classroom settings, the teacher influences learners' academic self-efficacy (ASE) levels. Self-efficacy is the set of beliefs about one's capabilities to learn or perform at designated levels (Bandura, 1994). Levels of self-efficacy contribute to a person's choices, effort, persistence, resilience, and achievement (Bandura, 1997). Self-efficacy has been studied in detail for a wide range of behaviors and situations, and ASE has been identified as a key factor in academic success (Marsh, Byrne, & Shavelson, 1988; Pajares & Miller, 1994; Schunk, 1982, 1984; Schunk & Pajares, 2001; Vrugt, Langereis, & Hoogstraten, 1997).

Academic self-efficacy is developed in many ways and in the realm of CAI mastery experience and feedback play major roles. Mastery experience is the most dominant source of ASE (Pajares & Schunk, 2001b), and learners who have answered questions correctly in the past have greater confidence in their ability to answer future questions correctly.

Feedback can be used to inform the learner of goal progress. Further, feedback has the potential to strengthen a learner's self-efficacy while sustaining motivation (Schunk & Pajares, 2001). Thus, well-designed CAI with meaningful feedback has the potential to affect learners' self-efficacy by providing opportunities for mastery experiences and motivating learners to further their individual understanding by increasing confidence in their abilities.

Though the areas of feedback and self-efficacy are extensively documented, what remains to be explored is how CAI feedback complexity affects levels of academic self-efficacy and achievement. Academic achievement can be measured in many ways. For example, a commonly used method of measuring achievement uses learner performance on objective-driven assessments that test the learner's ability to recall knowledge, solve problems, and apply old knowledge to new problems. Thus, in an effort to create CAI that provides an engaging learning environment that maximally increases academic achievement, it is necessary to explore further the interrelatedness of feedback in CAI, self-efficacy beliefs, and achievement.

Research Problems

The primary interest of this research is to investigate how different levels of feedback complexity in CAI affect both science self-efficacy and academic achievement. In theory, both feedback and high levels of self-efficacy have been linked to increased academic achievement. In addition, feedback and self-efficacy have been shown to interact with each other within a learner's cognitive state. However, the body of research concerning CAI feedback lacks a clear investigation into how the three interact overall. Additionally, due to conflicting results, previous research in the area of CAI feedback has not yielded any generalizable statements about how feedback complexity and achievement are related. Finally, a deficiency exists in the body of research due to the lack of investigations studying the effects of TC and RC feedback.

I prepared for this research by conducting two pilot studies using similar testing conditions. These studies helped me refine my research methods and forced me to narrow the focus of my research questions. After the first pilot, I discovered that I needed more than just numbers to understand the effects of the different treatment groups. I determined that some sort of follow-up investigation with participants was essential to explain the quantitative results. Thus, the second pilot utilized a mixed-methods design in an attempt to understand the effects of the different types of feedback on the learner. The combination of quantitative and qualitative methods facilitated a richer analysis of the data. So, I decided that the actual dissertation study should also follow a mixed-methods approach.

The overarching questions I address in this study are (a) How does feedback in chemistry CAI affect students' levels of science self-efficacy? and (b) How does feedback in science CAI affect student achievement on an objective-driven assessment? I narrowed these questions for the sake of clarity, specificity, feasibility, and importance to include: (a) Do different types of feedback in science CAI, namely KOR, KCR, KCR+, topic contingent, and response contingent, affect learners' levels of science self-efficacy? (b) Do different types of feedback in science CAI, namely KOR, KCR, KCR+, topic contingent, and response contingent, affect learners' scores on an objective-driven science assessment? (c) How do learners use different levels of feedback provided in science CAI modules? and (d) How do different types of feedback affect how confident a learner is in her or his ability to understand science?

Overview of Methodology

For this study, I used a mixed-methods approach, and I collected the quantitative and qualitative data concurrently. For the quantitative approach, I used a true-experimental design. I drew participants from students at the suburban high school in southeast Denver where I worked at the time of the study. All of the students were enrolled in general chemistry, but none of the dissertation participants were currently enrolled in one of the classes that I taught. Participation in the study was optional and required informed consent from both the student and her or his legal guardian.

The data I collected for the quantitative portion of the study included two measures, administered as a pretest and as a posttest. The first measure assessed the participants' level of science self-efficacy using a Likert-type response format on an established measure developed by Britner and Pajares (2001a). The second measure addressed academic achievement, as measured using a multiple-choice, objective-driven assessment of the chemistry concepts covered in the unit.

At the same time, I collected qualitative data in the form of journal responses and follow-up interviews. All learners participating in the study completed each journal response. Based on these responses and the quantitative data, I purposefully selected several students for a follow-up interview. The purpose of the interview was to triangulate evidence for the journal responses as well as provide an opportunity to ask more in-depth questions about the participants' learning experiences and what contributes to developing their science self-efficacy.

It is difficult to quantify the construct of science self-efficacy. Further, because of my experiences with high school science students, I argue that it is also very difficult to describe how different learners use feedback presented in CAI. Thus, by collecting data both quantitatively and qualitatively, I was able to develop a better understanding of the research phenomenon. By employing a concurrent triangulation strategy (Creswell, 2003), I was able to confirm, cross-validate, and corroborate findings within a single study. Also, it allowed me to gain a broader perspective of how feedback is used by learners in CAI and how it may influence learners' levels of self-efficacy and achievement.

Theoretical Framework

The three main concepts that this study attempts to interrelate are the development of ASE, feedback levels in CAI, and academic achievement. The body of literature for each of these topics individually is extremely extensive, but a logical connection exists between them via Albert Bandura's social-cognitive theory (1986) and the five-stage model of feedback processing proposed by Bangert-Drowns, Kulik, Kulik, and Morgan (1991).

Bandura's Social Cognitive Theory (1986) details how individuals' self-efficacy (i.e., beliefs about their ability to complete tasks) can influence their control and management of learning. Of the various sources of self-efficacy (i.e., mastery experiences, vicarious experiences, verbal persuasion, and individuals' psychological and emotional states), mastery experiences and verbal persuasion are two facets that feedback within CAI has the potential to influence. Computer-assisted instruction can provide a potentially infinite number of questions to promote the positive effects of mastery experiences through learners' engaging in CAI that offers multiple opportunities for success. Bandura's model also specifically targets verbal persuasion as a source of self-efficacy beliefs and well-programmed CAI can deliver feedback as elaborate as a human voice giving encouragement to the learners to help them avoid focusing on personal deficiencies.

The Bangert-Drowns et al. (1991) model focuses on the mindful processing of feedback by the learner. They posited that learners not only respond to questions with a particular level of certitude, but also their mindful evaluation of the feedback provided to the response given can affect several of the learners' states, namely self-efficacy, interests, and goals. These changes to the learners' states can affect further learning experiences by altering the initial states of the learners in subsequent, similar environments.

Additionally, according to these established theories, a learner's level of self-efficacy for a given task can be directly affected by the evaluation of feedback provided to him or her in a learning environment. Moreover, the learner's ability to evaluate her or his response depends on the feedback provided. It is reasonable, then, to expect that this feedback must also be of a quality that can encourage the reflective practices necessary for the learner's evaluation of her or his response to promote positive gains to the various states.

Finally, multiple connections between ASE and academic success have been widely researched throughout the last two decades (e.g., Pintrich & DeGroot, 1990; Schunk, 1991). Studies have shown that a student's beliefs about her or his ability to complete specific academic tasks directly affects her or his potential for realizing academic successes (Bong, 2002, 2004; Pajares & Miller, 1995; Pajares & Schunk, 2001a).

A Review of Selected Literature

A vast body of research focuses on feedback in instruction, computer-assisted instruction, and self-efficacy. Notable educational psychologists such as Skinner, Bangert-Drowns, Bandura, Pajares, and Schunk have contributed decades of quantitative and qualitative research aimed at better understanding these constructs. Because this dissertation focuses on the interaction between feedback in computer-assisted instruction and learners' academic self-efficacy, the following review of the literature is an attempt to narrow the emphasis of these wide-ranging topics to the most relevant information related to this dissertation.

I begin with a brief description of Albert Bandura's (1986) social cognitive theory and the construct of self-efficacy, how it is developed, and the importance of self-efficacy for academic success. Many reviews of the literature focused on academic self-efficacy research exist (e.g., Albion, 2001; Bandura, 1994; Britner & Pajares, 2001a; Gecas, 1989; Maddux, Norton, & Stoltenberg, 1986); therefore, I only highlight the essential conclusions of various individual studies and reference the existing meta-analyses of the larger body of research.

Next, I provide a brief history of the evolution of feedback research. Following this summary, I present a more thorough discussion of the feedback processing model proposed by Bangert-Drowns et al. (1991) and its relationship to the learner's cognitive state. Then, I discuss the specific connection to computer-assisted instruction and the types of feedback provided in these self-regulated learning environments. Past research has typically focused on the relative effects of different types of feedback organized according to the complexity of the feedback response on academic achievement. I provide an example of each of the six types of feedback (knowledge of response, answer until correct, knowledge of correct response, knowledge of correct response with elaboration, topic contingent, and response contingent).

Finally, the conclusion of this review guides the reader through the overall progression of thought leading to my specific interest in connecting feedback to self-efficacy in computer-assisted instruction. I end by identifying the links between these three topics and how they relate to the research questions and define the study's design.

Self-Efficacy Defined and Explained

Bandura's (1986) social cognitive theory posited that humans have the "capacity to exercise control over the nature and quality of one's life" (Bandura, 2001b, p. 1). This theory is grounded in the ability of one to express personal agency; therefore, Bandura posits that one must consider people's beliefs about their own capabilities when investigating differences between those people. Thus, self-efficacy, or the set of beliefs about one's capabilities to learn or perform at designated levels, plays a pivotal role in social cognitive theory (Bandura, 1994). These beliefs directly affect a person's ability to persevere and ultimately succeed at a given task.

Many factors influence the development of self-efficacy. First, personal mastery experiences positively affect an individual's self-efficacy because previous success at a given task raises the individual's perception of her or his ability to accomplish the task again. Even if the two tasks are not directly related, it is possible that success at something the individual determined was difficult would encourage the individual to tackle other perceived difficult tasks. Second, vicarious experiences play a role in the development of self-efficacy. If someone whom an individual identifies as being similar to herself or himself is successful at a given task, then the individual is more likely to determine that he or she has a likelihood of success as well. Third, social persuasion in the form of verbal or written communication increases an individual's self-efficacy, especially if the persuasion is realistic to the individual's abilities and talents. Finally, somatic and emotional states, or how emotional and physical reactions to certain activities are interpreted, can positively or negatively influence self-efficacy perception.

Levels of self-efficacy contribute to a person's choices, effort, persistence, resilience, and achievement (Bandura, 1997). Numerous examples show how people in the face of rejection continue trying and eventually succeed. For example, Thomas Edison failed 1000 times before successfully inventing the light bulb. Another example of perseverance is that football coaches Tom Landry, Chuck Noll, Bill Walsh, and Jimmy Johnson accounted for 11 of the 19 Super Bowl victories from 1974 to 1993. They also share the distinction of having the worst records of first-season head coaches in NFL history: They did not win a single game (Pajares, 2001). These are just a couple of testaments to the idea that people with high self-efficacy will choose to continue exerting effort towards a particular achievement and ultimately succeed because of their persistence and resilience.

The Development of Academic Self-Efficacy

While self-efficacy has been studied in detail for a wide range of behaviors and situations, it is especially important when exploring academic success. The development of academic self-efficacy (ASE) is complex in the sense that many different people and situations influence its development. Academic self-efficacy is first developed during childhood. The first environment that a child encounters that affects the development of her or his self-efficacy is the home (Schunk & Pajares, 2001). Familial influences are responsible for a wide range of possible self-efficacy effects. Households that encourage a child's curiosity through parental interaction and supplemental materials accelerate the child's development of positive self-efficacy for various tasks (Meece, 1997). Additionally, when parents provide a wide range of mastery experiences, the child is more-efficacious than other children who did not receive the same type of varied experiences (Bandura, 1997).

The Role of Parents

Parents play an important role in providing vicarious experiences by modeling coping strategies and persistence for their child. A child who is witness to the communication and troubleshooting processes that are used to solve various household troubles learns vicariously how to approach other problem-solving ventures on her or his own (Bandura, Barbaranelli, Caprara, & Pastorelli, 2001). Finally, as sources of persuasive information, parents can steer their child positively towards higher self-efficacy. For example, if parents encourage their child to meet lots of different challenges by guiding him or her towards multiple and varied activities, then they will increase the child's self-efficacy towards approaching different tasks (Schunk & Pajares, 2001).

The Role of Peers

Outside of the home, peers play an important role in the development of children's self-efficacy (Schunk, 1987). First, self-efficacy is greatly impacted by the vicarious experiences of a child's peers. When a child witnesses a peer succeed or fail at a particular activity, then the other child's success or failure influences the child's individual perceptions of her or his likelihood of success or failure.

Peers are also responsible for the probability of academic success for an individual (Steinberg, Brown, & Dornbusch, 1996). In a study monitoring students from high school entrance through their senior year, researchers observed that students are greatly influenced in their academic success by the peers with whom they associate. Upon entering high school, if one student with similar grades to a second student chooses to associate with academically motivated peers, then he or she will have higher academic success than a student who chooses a less academically motivated crowd.

The Role of Schools

The role of the school in the development of ASE changes from early childhood through adolescence in a manner inversely related to the role of peers. The school's ability to increase self-efficacy declines throughout this time, most likely due to less individualized attention, more norm-referenced tests, greater competition, and the impact of school transitions (Pintrich & Schunk, 1996). When students are in elementary school, teachers typically have 22 children each. In middle school, these numbers increase to around 80 children per teacher. During high school, each teacher has around 140 students. Consequently, as a person progresses through the traditional school system, her or his chance for individual attention from a teacher decreases as the student-teacher ratio increases. Less personalized time with the teacher negatively affects the development of academic self-efficacy because teachers provide verbal persuasion that may affect the individual student's level of ASE (Hattie, 2002). Further, as students advance through traditional schooling, they are exposed to more and more norm-referenced tests. The comparison of an individual to peers can have a negative effect on self-efficacy development if the student scores below average on the various measures. As the number of students in the classes and schools increases, so does the amount of competition each student must face. A greater probability of failure is likely when compared to another and may lead to the diminishment or underdevelopment of academic self-efficacy (Schunk & Pajares, 2001). Finally, the process of moving from the small, safe environment of an elementary classroom to the large bustle of high school creates uncertainty. Both the environment and the number of peers that a student knows changes; and in high school, students are forced to change their expectations for assessment as well as have a highly expanded social group to navigate. Thus, when reevaluating their academic abilities, many students reduce their personal expectations given their new surroundings (Harter, 1996).

Factors Affecting Academic Self-Efficacy

Another area of focus for ASE research investigates the different factors that affect levels of ASE. Most of this research appears to be at the post-secondary level and often focuses on how different instructional strategies influence self-efficacy. A study at Indiana-Purdue University at Fort Wayne investigated the effects of a communication designed specifically to enhance the self-efficacy of introductory psychology students (Jackson, 2002). By email, the instructor provided students with efficacy-enhancing messages or neutral replies to student inquiries and monitored the effect of these communications on test performance. Self-efficacy beliefs were both significantly related to exam scores and significantly affected by the efficacy-enhancing communication. Another study at the collegiate level analyzed the effects of reciprocal peer tutoring (RPT) on self-efficacy and exam performance (Griffin & Griffin, 1997). While previous research indicated that RPT positively influences achievement and reduced participants' level of stress and anxiety, the Griffin and

Griffin study showed no significant differences between RPT and non-RPT group performances on academic measures or academic self-efficacy.

Self-Efficacy as a Context-Specific Construct

Self-efficacy is known as a context-specific construct (Kiamanesh, Hejazi, & Esfahani, 2004; Zimmerman, 1995). Numerous studies have investigated the differences in ASE within specific content areas (Bong, 2002; Joo, Bong, & Choi, 2000; Marsh, 1992; Marsh, Walker, & Debus, 1991; Pajares & Miller, 1994, 1995, 1997). These studies suggest that not only do the predictive abilities of ASE measures increase when the measure focuses on one content area and performance within that area, but they also imply that the self-efficacy outcome links are stronger within the same domain than across different domains (Joo et al., 2000).

Bong (2002, 2004) took this facet of ASE measurement a step further and investigated three different levels of specificity in two different subjects to analyze any cross-domain interactions. This study allowed Bong to add additional support to the argument for specificity within a context domain, and it allowed her to test whether self-efficacy actually demonstrates stronger relationships with performance measures in the same subject area than with performance measures in a different area. Bong concluded that self-efficacy perceptions in a specific school subject were content specific to achievement. In other words, English self-efficacy predicted only

English achievements, and math self-efficacy predicted only math achievements. Cross-domain predictions were weak and not statistically significant.

Relationship Between Levels of ASE and Academic Achievement

Finally, ASE has direct influence on levels of academic achievement. Linnenbrink and Pintrich (2002) stated, "Experimental and correlational research in schools suggests that self-efficacy is positively related to a host of positive outcomes of schooling such as choice, persistence, cognitive engagement, use of self-regulatory strategies, and actual achievement" (p. 315). Further, low academic self-efficacy has been connected to higher incidences of academic cheating, especially among high-achieving students (Finn & Frone, 2004).

Numerous studies investigate the correlation between ASE and exam performance. House (2000a, 2000b) focused his research on how academic background and self-beliefs can serve as predictors for performance in science, engineering, mathematics, and health science majors. He found that self-beliefs accounted for 20% of the variance in students' cumulative grade point averages.

Research on self-regulated learning is also closely tied to academic self-efficacy and suggests that students with high efficacy are more apt to be successful in self-regulated learning environments (Miller, 2000; Pajares, 2002; Zimmerman, 2002). This area of research also connects to differences in gender and academic self-efficacy because, in general, girls have more goal-setting and planning strategies, keep records, and self-monitor more frequently than boys, lending them a higher self-efficacy for those tasks (Pajares, 2002). Research on the malleability of self-efficacy beliefs and grade goals as predictors of exam performance (Vrugt et al., 1997; Wood & Locke, 1987) continues to confirm other bodies of research that positively correlate levels of self-efficacy to levels of achievement.

Connecting Self-Efficacy Development to Feedback in CAI

While many factors influence the development of self-efficacy, because CAI modules are generally completed in isolation from other learners, most of the self-efficacy changes in an individual result from mastery experiences. Mastery experiences, in the form of question practice, integrate the use of feedback to the learner. Another possible source of self-efficacy enhancement in CAI resides in the social persuasion influences that come from efficacy-enhancing statements and praise for correct answers. Therefore, even though CAI removes the human teacher from the learning environment, it may still be possible to affect changes to an individual learner's level of self-efficacy. Computer-assisted instruction has its roots in the theories and practices of programmed instruction. Thus, to understand how feedback in CAI is structured, it is necessary to review the history of programmed instruction and its behaviorist connections in psychological research.

Early Research Leading to Programmed Instruction

Thorndike's (1933) Law of Effect has often been cited as one of the most influential contributions to early behavioral and academic research (e.g., Herrnstein, 1970; Kulhavy & Wagner, 1993; Mory, 2004). Thorndike was one of the first researchers to recognize the interaction of biology with learned behavior. The foundation of his law lies in a Darwinian perspective that the connections of neural synapses connections are strengthened when a behavior results in a positive reward while these same connections are weakened when behaviors are punished.

This early biological approach to learned behavior became widely accepted as a foundational premise of psychology and education, as evidenced by a quote in a letter from B. F. Skinner to Thorndike in 1939, cited in Cummings (1999), apologizing for not acknowledging Thorndike in the publication of *The Behavior of Organisms*: "I seem to have identified your view with the modern psychological view taken as a whole" (p. 429). Thorndike's research on instrumental conditioning, or providing positive and negative feedback to elicit a desired response, fits neatly into a Skinnerian perspective on behavior modification and learning theory (Salamone & Correa, 2002).

Feedback as Reinforcement

Much of B. F. Skinner's (1960) contributions to modern psychology were encouraged by Thorndike's (1933) Law of Effect. These contributions eventually paved the way for the founding principles of programmed instruction. Programmed instruction originated as a series of predetermined linear steps for the learner to progress through for the purpose of learning a particular task or concept (Mory, 2004). Feedback's primary purpose within the programmed instruction context is to reinforce answers. Skinner's work with rats and pigeons gave evidence that animals learn behaviors when exposed to various stimuli to elicit a desired response. If that desired response was given, then a positive reinforcement (e.g., a food treat) was awarded (Gilbert & Gilbert, 1991). While certain researchers criticized Skinner for attempting to connect his work with animals to humans, further research showed that this behaviorist approach has merits for influencing certain behaviors and type of learning (Mory, 2004).

By the mid 1970s, various researchers began to express doubts as to the efficacy of feedback as an appropriate and effective reinforcer of correct responses (Kulhavy, 1977). In his review of the literature on feedback in programmed instruction, Kulhavy defined feedback as any number of ways used to inform a learner of the correctness of her or his response. This comprehensive review of the literature regarding programmed instruction found no significant and repeatable evidence to suggest that increasing feedback complexity results in corresponding increases in learning. Further, Kulhavy and Anderson (1972) concluded that feedback does not act as a reinforcer based on evidence of immediate and delayed feedback comparisons.

Doubts Concerning Feedback's Ability to Promote Understanding

With previous claims as to the ability of feedback as a reinforcer in behaviorist approaches to education refuted (Kulhavy, 1977), Kulhavy and Stock (1989) sought to understand the model of how feedback processing occurs within an individual's mind, in hopes of gaining a better understanding of why the results from so many studies conflicted. Presearch availability, or the ability for a learner to find the answer to a given question without processing the information provided (e.g., copying the answers from the back of the book), was blamed for many of the conflicting results on the efficacy of feedback to serve as a positive reinforcer (Kulhavy, 1977; Mory, 2004). Bangert-Drowns et al. (1991) furthered the investigation into the confounding results of previous feedback research by introducing the idea that feedback is most effective in promoting learning if it is provided in a context that encourages the learner to mindfully process the feedback information.

Bangert-Drowns: Response Certitude and Mindfully Processed Feedback

The five-stage model of learning posited by Bangert-Drowns et al. (1991) acknowledges the importance of mindfully processing feedback to effect a change in the learner's cognitive state (see Figure 1.1). To describe each of the stages, a learner's thought processes and responses to the feedback are depicted in terms of his behaviors and actions. In the first stage, the authors acknowledge that the learner's initial state in terms of his previous experiences, knowledge, individual goals, and self-efficacy set the tone for whether or not feedback is likely to positively affect his cognitive state in the form of increased understanding. The initial state also acknowledges that if the learner has a certain amount of apathy for the type of instruction, then he may not even attempt to mindfully process the feedback, from either boredom or general disinterest.

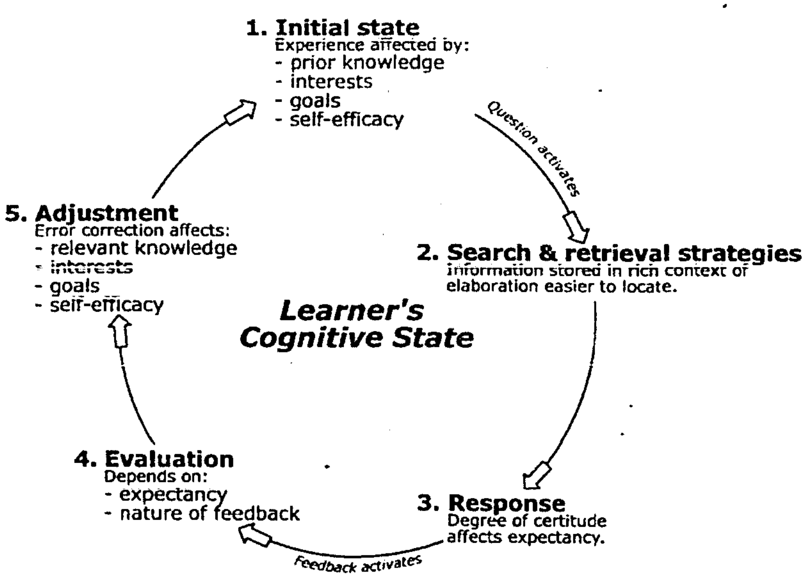

Figure 1.1 The State of the Learner Receiving Feedback

Based on Bangert-Drowns et al. (1991; from Dempsey, Driscoll, & Swindell, 1993). From Interactive Instruction and Feedback (p. 40), by J. V. Dempsey and G. C. Sales (Eds.), (1993), Englewood Cliffs, NJ: Educational Technology.

Assuming that a learner advances to the second stage, his search and retrieval strategies are activated by the question posed. How well he is able to access information related to the question depends on many factors; however, the model assumes that information that has been previously stored within elaborate contexts is recalled more easily during this stage than information that was not stored in elaborate contexts. For example, if a learner had previously learned the order of the planets from the sun using only a mnemonic (My-Very-Educated-Mother-Just-Served-Us-Nine-Pizzas to recall Mercury-Venus-Earth-Mars-Jupiter-Saturn-Uranus-Neptune-Pluto), then he would probably be able to retrieve the correct order. Nevertheless, he may not have access to the more elaborate details such as the planets' relative sizes and distances from the sun.

However, if the mnemonic were combined with an activity that involved building a scale model of the solar system (an activity which, when done correctly, involves objects ranging in size from a pea to a beach ball, and a large parking lot to simulate the sizes and distances), then he would be more likely to be able to retrieve information with more details intact.

The learner's response to the question constitutes the third stage in this feedback-processing model. At this point, the learner's level of certitude about his response plays an important role in how his cognitive state is affected. If he is very certain that his response is correct, then he has a preconceived notion as to what type of feedback he will receive as a result of answering the question. After giving his response, he is provided with feedback as to the correctness of his response.

In the final stages, evaluation and adjustment, a learner's response certitude can affect the learner's new initial state for future questions. These final two stages depend on how a learner responds to the feedback provided. If a learner responds to the question with a high degree of certitude and has his answer validated by the feedback for its correctness, then two outcomes are possible. If the feedback is mindfully processed and it agrees with the learner's expectations, then this matched-pair of learner expectations and actual outcome strengthens the retrieval pathway used to determine the initial response (Kulhavy, 1977; Kulhavy & Stock, 1989). This argument is reminiscent of the early theories of Thorndike and his Law of Effect (1933) in that a reward for a correct response acts as a positive reinforcer of the learned behavior. Also possible is an increase in the learner's self-efficacy for answering that type of question. However, even if the retrieval pathway and learner's self-efficacy are strengthened, there is no net gain in actual knowledge. In contrast, when feedback validates a correct response but the learner fails to process the feedback information meaningfully, he fails to use the feedback in any way to strengthen his future ability to retrieve similar information. Thus, there is no net gain from the feedback in the form of strengthening the retrieval pathway or by increasing actual knowledge.

If the learner's response is correct, but he was only marginally certain of the answer's correctness, there are again two possible outcomes depending on how the feedback is processed. A response for which the learner has little confidence that it is actually correct may result in mindful feedback processing as a result of learning that he was initially correct. This mindful processing may lead to a greater understanding and overall net knowledge gain. Additionally, the learner may benefit from an increase in self-efficacy because of this mastery experience. On the other hand, the learner may not process the feedback mindfully. Unless the learner is actually interested in gaining the knowledge, he or she is not likely to devote energy to mindfully processing the feedback about a correct response for which he did not have a high degree of certitude. However, he may still benefit from a gain in self-efficacy due to the mastery experience of getting a correct answer.

In contrast, when the learner's response is incorrect, he encounters feedback that could be discouraging and inhibit her or his willingness to mindfully process the feedback with the ultimate goal of increasing knowledge. In the situation where the learner has a high degree of certitude for the correctness of his response, the learner is forced to realize that he, though highly confident in his response, was actually incorrect. The cognitive dissonance from this scenario can result in extremely meaningful reflection, assuming the feedback is mindfully processed. However, the feedback may not be mindfully processed in this scenario if the learner is inhibited by frustration or anger after learning that the answer he was highly confident about was, in fact, incorrect. Thus, no net gain in knowledge may result, and it is even possible that the learner loses self-efficacy for answering similar questions.

Finally, learner may not have a lot of confidence in the correctness of his answer, and thus, learning that he was incorrect does not cause any true cognitive dissonance. The learner's willingness to mindfully process the incorrect feedback for a low certitude response depends strongly on his interest in the question and in his desire to gain understanding and increase his knowledge. A genuinely interested learner may approach feedback about an uncertain response with the intent to better understand the gap in his knowledge and strive to use the feedback to fill the preexisting hole in his understanding. When approached mindfully, an uncertain, incorrect response can also result in highly beneficial reflective practices, thereby increasing the individual's understanding and self-efficacy to answer similar questions correctly in the future. In contrast, if the learner has no stake in gaining understanding and knowledge related to the question and feedback, he is not likely to exert the mental energy necessary to mindfully process the feedback thoroughly. Thus, the feedback has little or no effect on the learner's cognitive state.

The cyclical nature of the Bangert-Drowns et al. (1991) feedback processing model acknowledges that the development of knowledge and understanding is not only a multi-faceted process, but also affects future learning interactions. How a learner responds to a particular question and how she evaluates and adjusts her or his understanding based on her or his certitude and correctness in turn alters her or his initial state for future questions. Thus, it is essential to encourage learners to use any feedback provided in a meaningful way; and reflective practice should be facilitated during the evaluation and adjustment stages. Only by mindfully processing feedback is it possible to increase understanding and gain knowledge. Furthermore, self-efficacy may be influenced as a result of the feedback provided. Because self-efficacy and academic performance are inextricably linked, it is also beneficial to the learner to have opportunities to enhance her or his individual confidence for answering future, similar questions correctly (Pajares, 1996; Schunk, 1991; Schunk & Pajares, 2001; Schunk & Swartz, 1993; Walker, Greene, & Mansell, 2006).

Feedback Approaches and Connections to Computer-Assisted Instruction

Feedback is defined as information presented to the learner after any input with the purpose of shaping the perceptions of the learner (Sales, 1993). This definition closely resembles a behaviorist or programmed instructional approach to the purpose of feedback as a reinforcement of a desired response (Mory, 2004). The cognitivist definition emphasizes more than simple reinforcement of correct answers in that the purpose of feedback is to act as more of a source for information designed to provide insight and understanding about the question posed (Narciss, 2002).

These two approaches to defining feedback (i.e., behaviorist and cognitivist theories) have driven the research surrounding feedback in computer-assisted instruction (CAI). The focus of the cognitivist approach is on the information-processing connection between feedback and learners. Because this type of feedback must provide a source of information about the question instead of only identifying the correct response, it requires more knowledge and effort on the part of the CAI developer.

Classification and Research on the Effects of Feedback Types in CAI

The relative effects of different types of immediate feedback interventions, classified according to the amount of feedback provided in computer assisted instruction (CAI) on academic achievement is a commonly investigated topic in educational research. From the simplest level, which contains the least information, to the most complex level, feedback research focuses on (a) knowledge-of-response (KOR), (b) answer-until-correct (AUC), (c) knowledge-of-correct-response (KCR), (d) knowledge-of-correct-response plus elaboration (KCR+), (e) topic-contingent (TC), and (f) response-contingent (RC) (summarized from the works of Catania, 1999; Clariana, 2001; Clark & Dwyer, 1998; Gordijn & Nijhof, 2002; Mason & Bruning, 1999).

Feedback from the Behaviorist Perspective

The types of feedback that are most closely related to the behaviorist approach for the function of feedback are knowledge-of-response (KOR), answer-until-correct (AUC), knowledge-of-correct-response (KCR), and knowledge-of-correct-response plus elaboration (KCR+). These various levels of CAI feedback are often classified together because they use very straightforward feedback prompts to inform the learner of her or his accuracy after answering a question. The simplest of these feedback types is KOR, in which learners are provided with prompts such as *correct* or *incorrect* immediately after answering a question. Knowledge-of-response is sometimes combined with AUC and allows the learner to select additional choices until he or she answers correctly. Knowledge-of-correct-response feedback provides the learner with the identity of the correct response immediately after he or she inputs an answer, whether correct or incorrect, without allowing him or her to try again. Knowledge-of-correct-response plus elaboration feedback includes additional information for the learner to process; which often takes the form of a hint to help guide him or her to the correct answer and includes AUC directions. Tables 1.1-1.4 compare and contrast these four types of feedback as to how the feedback is presented to the learner and as to how many chances the learner has to answer the question correctly.

Table 1.1 Example of KOR feedback

The learner has one chance to get the question correct.		
Question: What is the chemical formula for the ionic compound made from the elements oxygen and aluminum?		
Choice	Response text	Feedback displayed when the response is selected
A	OAl	Incorrect
B	Al_2O_3	Correct
C	Al_3O_2	Incorrect
D	O_3Al_2	Incorrect
E	AlO	Incorrect

Table 1.2 Example of AUC feedback

The learner has multiple tries to get the answer correct.		
Question: What is the chemical formula for the ionic compound made from the elements oxygen and aluminum?		
Choice	Response text	Feedback displayed when the response is selected
A	OAl	Incorrect. Try again.
B	Al_2O_3	Correct.
C	Al_3O_2	Incorrect. Try again.
D	O_3Al_2	Incorrect. Try again.
E	AlO	Incorrect. Try again.

Table 1.3 Example of KCR feedback

The learner has one chance to get the question correct.		
Question: What is the chemical formula for the ionic compound made from the elements oxygen and aluminum?		
Choice	Response text	Feedback displayed when the response is selected
A	OAl	Incorrect. The correct response is B.
B	Al_2O_3	Correct
C	Al_3O_2	Incorrect. The correct response is B.
D	O_3Al_2	Incorrect. The correct response is B.
E	AlO	Incorrect. The correct response is B.

Table 1.4 Example of KCR+ feedback

The learner has multiple tries to get the answer correct.

Question:

What is the chemical formula for the ionic compound made from the elements oxygen and aluminum?

Choice	Response text	Feedback displayed when the response is selected
A	OAl	Incorrect. See page 293 in your chemistry textbook for help. Try again.
B	Al_2O_3	Correct
C	Al_3O_2	Incorrect. See page 293 in your chemistry textbook for help. Try again.
D	O_3Al_2	Incorrect. See page 293 in your chemistry textbook for help. Try again.
E	AlO	Incorrect. See page 293 in your chemistry textbook for help. Try again.

Feedback from the Cognitive Perspective

The levels of feedback complexity that relate most closely to the cognitivist approach all facilitate more complex interactions between the learner and the feedback provider by focusing on the nature of the response provided by the learner. Topic-contingent (TC) and response-contingent (RC) feedback interventions contain specific information to help the learner determine the correct answer and are tailored to the type of question and the response given. Feedback designed to provide specific information about a particular topic or concept (TC) is a more elaborate form of KCR+ because it increases the amount of information provided to the learner during the feedback interaction. While KCR+ may provide the learner with additional information (e.g., a page number in the textbook where information about the question can be located), TC provides a specific feedback prompt designed to address the focus of that particular question. For example, a CAI module may ask a question about writing a chemical formula from its constituent elements. If the learner selects an incorrect answer, the KCR+ feedback would prompt the student to review her or his notes and read page 293 of the chemistry textbook for help on writing the correct formula. In contrast, TC feedback would prompt the student to use the periodic table to determine the charge of each of the elements in the ion form and provide a hint on how to combine the elements together.

Response-contingent feedback adds one more level of elaboration to the feedback provided when an incorrect response is selected. Instead of giving feedback that is specific to the topic of the question, RC assumes that the learner made some sort of cognitive error when he or she selected a particular answer and the feedback provided is designed to address the error he or she made. Tables 1.5-1.6 compare and contrast these two types of feedback as to how the feedback is presented to the learner and as to how many chances the learner has to answer the question correctly.

Table 1.5 Example of TC feedback (cognitivist approach)

The learner has multiple tries to get the answer correct.

Question:

What is the chemical formula for the ionic compound made from the elements oxygen and aluminum?

Choice	Response text	Feedback displayed when the response is selected
A	OAl	Incorrect. Remember, when writing formulas, the charge of the ionic compound must add up to zero and the cation should be written before the anion. Try again.
B	Al_2O_3	Correct
C	Al_3O_2	Incorrect. Remember, when writing formulas, the charge of the ionic compound must add up to zero and the cation should be written before the anion. Try again.
D	O_3Al_2	Incorrect. Remember, when writing formulas, the charge of the ionic compound must add up to zero and the cation should be written before the anion. Try again.
E	AlO	Incorrect. Remember, when writing formulas, the charge of the ionic compound must add up to zero and the cation should be written before the anion. Try again.

Table 1.6 Example of RC feedback (cognitivist approach)

The learner has multiple tries to get the answer correct.

Question:

What is the chemical formula for the ionic compound made from the elements oxygen and aluminum?

Choice	Response text	Feedback displayed when the response is selected
A	OAl	Incorrect. When writing ionic formulas, which element always goes first? What are the charges of the two ions? Think about these hints and try again.
B	Al_2O_3	Correct. Aluminum, the metal, assumes a 3+ charge in its ionic form. Oxygen, the nonmetal, takes on two additional electrons to form O^{2-} ions. Thus, to make the overall compound neutral, 2 Al^{3+} and 3 O^{2-} ions are required resulting in the correct ionic formula unit Al_2O_3. Great job!
C	Al_3O_2	Incorrect. You're really close… but I think you got confused with the charges of each ion. Aluminum will lose three electrons – that makes it what charge? Oxygen gains two electrons. Now, put the elements together so that the net charge of the ionic compound is zero. Try again, you can do it!
D	O_3Al_2	Incorrect. Which of these elements is the metal? What order should the elements in an ionic formula be given? Use your periodic table to identify the metal and the nonmetal in this question and try again – you're almost there!
E	AlO	Incorrect. When forming ionic compounds, the net charge of the overall formula unit must add up to zero. Now, using the periodic table to guide you, what are the charges of each of the two elements in this question when they form stable ions? Work carefully and you'll get it right!

Relative Effects of Feedback Complexity on Academic Achievement

Numerous studies have investigated the relative effects of the more simple feedback types (i.e., KOR, AUC, KCR, and KCR+) on academic achievement (e.g., Clariana, 2001; Clark & Dwyer, 1998; Gordijn & Nijhof, 2002). However, while the designs of these studies often are similar, the researchers' fail to combine to create a body of evidence either in support of or against a hypothesis that states that increasing feedback complexity also increases academic achievement (see reviews in Azevedo & Bernard, 1995; Clariana, 1993; Mory, 1996, 2004).

Many studies exist investigating the effects of the more elaborate feedback types (i.e., TC and RC); however, the researchers' conclusions from these studies are inconsistent and thus, fail to create a convincing argument that the more elaborate forms of feedback are more effective for increasing academic achievement than less elaborate forms (see reviews by Bangert-Drowns et al., 1991; Clariana, 1993; Mason & Bruning, 1999; Mory, 1996, 2004). With such a large body of preexisting literature examining the effect of feedback on academic achievement that conflicts in the findings, one is led to seek alternative explanations for why the existing feedback research does not conclusively support any one type of feedback (i.e., KOR, AUC, KCR, KCR+, TC, and RC) as superior for having the greatest impact on learning.

Conclusion

The problem is that existing research focused on measuring how feedback in CAI affects achievement conflicts and fails to generate an understanding of the role that feedback in CAI plays in relationship to student achievement; thus, a different approach to understanding these failures is needed. The Bangert-Drowns et al. (1991) feedback processing model illuminates two features of how feedback can positively affect the learner's cognitive state that I believe can lead to a better understanding of why the previous research was inconclusive.

Thus, I designed my research not only to attempt to explain past research anomalies, but also to make recommendations for future improvements to the type of feedback programmed into CAI tools. By examining the relationship between the mindful processing of feedback and how it varies given different levels of feedback complexity and how these feedback differences affect the learner's level of self-efficacy, I hope to provide a description of why previous research has failed to find the *best* type of feedback for promoting academic achievement in CAI environments. I used both quantitative and qualitative methods to understand how all the concepts were connected. The quantitative methods were designed to answer the general questions of whether or not different levels of feedback complexity in CAI significantly affected the learners' academic achievement and the learners' self-efficacy. Qualitative methods were necessary to more completely describe how different learners approach CAI and the feedback provided within the learning tools, and whether or not these different approaches played a role in the measured quantitative changes.

Structure of the Dissertation

This dissertation is composed of five chapters. In Chapter 1, I have described the purpose, conceptual and theoretical framework; listed the research questions and hypotheses; and presented a brief overview of the methodology. Also, I reviewed the literature surrounding the concepts of feedback and self-efficacy. I describe the methodology of the study for both the quantitative and qualitative approaches in chapter two. For each approach, I address the sampling, measures, data collection and analysis procedures, and limitations. I present the quantitative findings in chapter 3 according to the research questions and hypotheses proposed and the qualitative findings in chapter 4. Finally, in chapter 5, incorporate the quantitative and qualitative findings to present conclusions based on these data. I highlight similarities and differences between this study and existing research, and suggest implications for future research. As I foreshadowed in the introduction to this dissertation, I also provide my own recommendations for CAI feedback design based on the findings of this study. In conclusion, I outline the limitations of this study and provide a description of how these limitations may have affected the study outcomes.

CHAPTER 2

METHODOLOGY

The driving research questions behind this study are (a) How does feedback in chemistry CAI affect student achievement on an objective-driven assessment? and (b) How does feedback in chemistry CAI affect students' levels of science self-efficacy? I completed two pilot studies in preparation for this research. The first study had two independent variables, gender and exposure to different types of feedback during a chemistry CAI module. The dependent variables were ASE and performance on an objective-driven assessment (ODA) of the chemistry concepts covered in the module. No significant changes in ASE across time were found. Also, no significance of the between-subjects or within-subjects effects for the ODA was observed. The second pilot investigated the same independent variables. Self-efficacy and achievement were also investigated; however, the more general ASE was narrowed to the content-specific science self-efficacy (SSE). A significant within-subjects effect for time was observed at a 95% confidence interval. Analysis of the means for SSE over time revealed an increase in SSE from pretest to posttest. No other meaningful significance of between-subjects or within-subjects effects for the ODA were observed at a 95% confidence interval. However, a mixed methods approach yielded valuable qualitative insights into why only one overall quantitative effect was observed.

Because of my findings from these pilots, I employed both quantitative and qualitative research methods. Academic achievement, as measured on a multiple-choice, objective-driven assessment, can be easily investigated using quantitative methods. However, self-efficacy is a social construct and thus, is less easily quantifiable. There exist Likert-type measures of self-efficacy that have yielded high levels of reliability and validity; but, to fully understand the phenomenon of self-efficacy and how it is related to feedback provided in CAI, qualitative methods must also be employed. Therefore, to capitalize on the strengths of each method, I used both quantitative and qualitative research methods. Additionally, the concurrent use of both methods of data collection provided unique opportunities for gathering triangulation evidence and generating a better picture of what types of feedback most impact the self-efficacy and, subsequently, the academic achievement of the learners.

The mixed-methods approach required me to break down the broader research questions further into questions that can specifically be answered by the two different approaches. The quantitative questions are: (a) Do different types of feedback in computer-assisted instruction modules affect the score of science students on an objective-driven chemistry assessment? and (b) Do different types of feedback in computer-assisted instruction modules affect students' levels of science self-efficacy? Qualitatively, these same questions can be approached from a more exploratory perspective. Tentatively, the primary qualitative research questions are: (a) How do students use different levels of feedback provided in computer assisted instruction modules? and (b) How do different types of feedback affect how confident a student is in her or his ability to learn science?

In this chapter, I address the quantitative and qualitative analyses separately. The data collection for both approaches occurred concurrently with the primary emphasis on the quantitative data analysis. I used the qualitative data to provide evidence of triangulation as well as to generate a more complete picture of how learners use feedback in CAI and what effects, if any, the feedback had on an individual's self-efficacy. I begin by discussing the quantitative analysis design, subject and sampling procedures, setting and materials, independent and dependent variables, the instrumentation used, data collection and analysis procedures, and the limitations of the methods chosen. In the qualitative section, I discuss the overall approach and rationale for my research, the qualitative site and population selection, my role as the researcher, the data collection methods, management and analysis procedures, and the limitations of the qualitative approach. Finally, a summary of the mixed methods approach will highlight the strengths and weaknesses of each design and how they overlap to provide a more complete analysis of the research questions.

Study Participants

The participants for this study were students enrolled in first-year general chemistry at a suburban high school in Centennial, Colorado. One hundred and ninety students were enrolled in nine sections of chemistry and 108 returned both the student and guardian informed consent forms signed. Participation in the study was optional, and no extra credit or other compensation was awarded to those who chose to participate. Of the 108 participants, 53 were male and 55 were female. All participants were sophomores, juniors, or seniors in high school; and their ages ranged from 16-18, with an overall mean age of 17. The ethnicity breakdown of the entire sample was 67.6% Caucasian, 12.0% African-American, 11.1% Asian-American, 8.3% Hispanic, and 1.0% of Middle-Eastern descent. The participants were randomly assigned to one of three treatment groups. The final data set, omitting any participants who did not complete one or more of the measures or treatments, consisted of 95 participants. The demographic information for each group is displayed in Table 2.1. Because gender, ethnicity, and age were not factors of this design, these values are provided as qualitative information only to help understand the limitations of the study for generalizing to a broader population. Permission to gather data was granted through the Human Subjects Review Committee (HSRC) at the University of Colorado at Denver and Health Sciences Center (Appendix D). Additionally, permission from school administrators was obtained on the condition that signed informed consents from both the student and the legal guardian were obtained before the start of the study (Appendices A-C).

Table 2.1 Demographic breakdown of the experimental groups

	Gender		Caucasian	African-American	Asian-American	Hispanic	Middle-Eastern
	M	F					
Group C (*N* = 36)	21	15	67%	17%	8%	4%	4%
Group D (*N* = 27)	13	14	77%	12%	8%	3%	0%
Group E (*N* = 32)	15	17	60%	12%	14%	14%	0%

Quantitative Analysis

Academic achievement is quantifiable when defined using scores on objective assessments of knowledge and understanding. Carefully constructed achievement tests can give a reliable and valid diagnostic evaluation of student progress, especially when the tests are clearly aligned to specific instructional objectives (Hopkins, 1998). Thus, the first research question, (i.e., do different types of feedback in chemistry CAI modules affect the scores of science students on an objective-driven chemistry assessment?) was addressed by quantifying the students' knowledge and understanding of the chemistry topics deemed essential to the unit on acid and base chemistry.

Self-efficacy is a social construct that is not as easily quantifiable. However, this construct has been widely investigated in numerous empirical studies (e.g., Mone, Baker, & Jeffries, 1995; O'Brien, Kopala, & Martinez-Pons, 1999; Pajares & Schunk, 2001a; P. L. Smith & Fouad, 1999; S. M. Smith, 2001; Wood & Locke, 1987; e.g., Zeldin & Pajares, 2000). Researchers have shown that self-efficacy can be measured with responses on a Likert-type scale to carefully worded, content-specific items (Bandura, 2001a; Pajares, 1996). Therefore, the second research question (i.e., do different types of feedback in chemistry CAI modules affect students' levels of science self-efficacy?) was addressed using an established measure of science self-efficacy that asked specific questions about the students' confidence to complete certain science tasks as well as how they perceived their science abilities.

Design

This study investigated the effects of different levels of feedback in CAI on participants' scores on an objective-driven chemistry assessment and on levels of science self-efficacy. The design for the study included two separate three-group, true-experimental designs. I randomly assigned participants to one of three different feedback groups, which varied in the type of feedback presented in the otherwise identical CAI modules. The pretests and posttests of the dependent variables occurred at the beginning and end of a three-week chemistry unit about acids and bases. The four different CAI modules composing the study's treatment were spread over the course of the unit, and each module administered a series of objective-driven chemistry practice multiple-choice questions. The independent variable, level of feedback, had three levels. These groups, labeled groups C, D, and E, varied in the type of feedback presented upon answering a question.

Group C participants received text-based KOR and KCR feedback. Group D participants received text-based KOR feedback for incorrect responses and KCR+ feedback for correct responses. The KCR+ feedback was delivered via both audio accompanying text captions. Group E participants received topic contingent and response contingent (TC/RC) feedback for incorrect responses and the same KCR+ feedback for correct answers as the group D participants. All feedback for group E participants was delivered using both audio and text captions. Table 2.2 summarizes the differences in feedback by group and response. For a more complete picture of how the modules varied by feedback provided, I have provided screen shots from each module of the same question in Figures 2.1-2.8.

Table 2.2 Feedback provided according to response and group

Group	Response	KOR	KCR	KCR+	TC/RC
C	Incorrect	✓			
	Correct	✓	✓		
D	Incorrect	✓			
	Correct	✓		✓	
E	Incorrect	✓			✓
	Correct	✓		✓	

The two dependent variables, investigated separately, were studied using an objective-driven chemistry assessment and self-reported level of science-self efficacy, as evaluated on a Likert-type measure. The objective-driven assessment (ODA) was composed of 60 multiple-choice questions that were aligned with the same textbook objectives as the CAI module questions. It is important to note that, to reduce effects of pretest sensitization, the questions on the ODA were not identical to the ones contained in the CAI modules. The 48-question measure of science self-efficacy was developed by Shari Britner and Frank Pajares and addresses facets of science self-efficacy such as (a) science anxiety, (b) science self-concept, and (c) self-efficacy for self-regulation (Britner & Pajares, 2001). The Likert-type scale ranged across six values, labeled according to the participant's individual confidence for completing a task, or the participant's self-beliefs as to how true or false a particular statement was when describing her or his own feelings and attitudes about learning science. I describe each measure more thoroughly in the *Dependent Variables* section of this chapter.

Settings and Materials

I conducted this study over 18 regularly scheduled class periods spanning 23 calendar days. All pretests and posttests were administered either during the participants' regularly scheduled class or during a study-period in the case of students who were absent for either the pretest or the posttest dates. The participants attended four scheduled sessions in the computer lab during which they completed the four CAI modules that accompanied the content covered previously in class. The computer lab contained 32 Macintosh computers, each equipped with an optical CD-ROM drive. Participants received a CD for their assigned group; and, if participants were in the D or E treatment groups, then each participant received a set of headphones. Prior to the second, third, and fourth visits to the lab, each classroom teacher was provided with a list of the individuals absent on the previous lab day(s) and instructions for getting those individuals caught up with the rest of the participants. Any other missed modules were completed in an optional computer lab session scheduled at the end of the study, before the posttests. Four different chemistry teachers had students participating in the study. However, effects due to teacher involvement were taken into account by the successful random assignment of participants to the different treatment groups.

Independent Variables

Participants were randomly assigned to one of three groups, which constituted the independent variable for the study. I provided the classroom teachers with four chemistry CAI modules for their students to complete throughout the course of the unit. I designed the CAI modules to consist of 18 to 21 multiple-choice questions that were aligned to the specific textbook objectives for the chapter on acid and base chemistry. The three levels of the independent variable differed according to the type of feedback was presented in response to incorrect and correct answers.

The modules for treatment group C were designed to deliver text-based KOR and KCR feedback only. A sample question from the first module is shown in Figure 2.1. When a participant in group C answered a multiple-choice question incorrectly, the text-based feedback on the screen simply stated, *Incorrect, try again.* If the answer was correct, then the feedback stated, *Correct. Advance to the next question.* Once the participant chose the correct answer, a button to advance to the next question appeared in the lower right-hand corner of the screen. Screen shots of an incorrect response and correct response example for group C are displayed in Figure 2.2 and Figure 2.3, respectively.

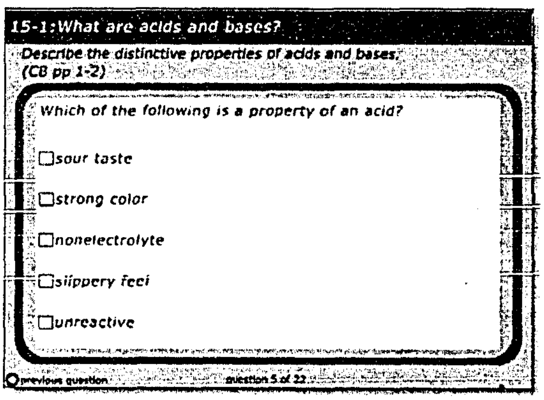

Figure 2.1 Sample Question from the First CAI Module

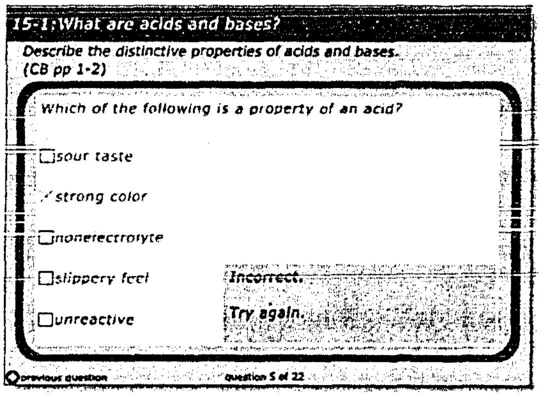

Figure 2.2 Example of KOR Feedback

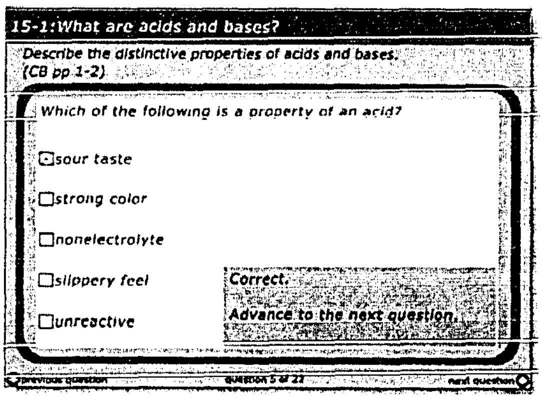

Figure 2.3 Example of KCR Feedback

Treatment group D received text based KOR feedback for incorrect responses identical to the group C incorrect feedback (Figure 2.2). However, when group D participants clicked on the correct answer, feedback that discussed why the chosen answer was correct (KCR+) was both displayed on the screen and heard from an audio sound track. The use of captioned audio feedback was employed to prevent the participant from skipping the feedback by simply clicking to the next question. The button to advance to the next question did not appear on the screen until the end of the feedback for the correct answer. Thus, to advance to the next question, the participant must determine the correct answer and listen to the entire KCR+ feedback. I have provided screen shots of the sequence of KCR+ feedback provided as text and audio for a correct response in one question from a group D module (Figure 2.4).

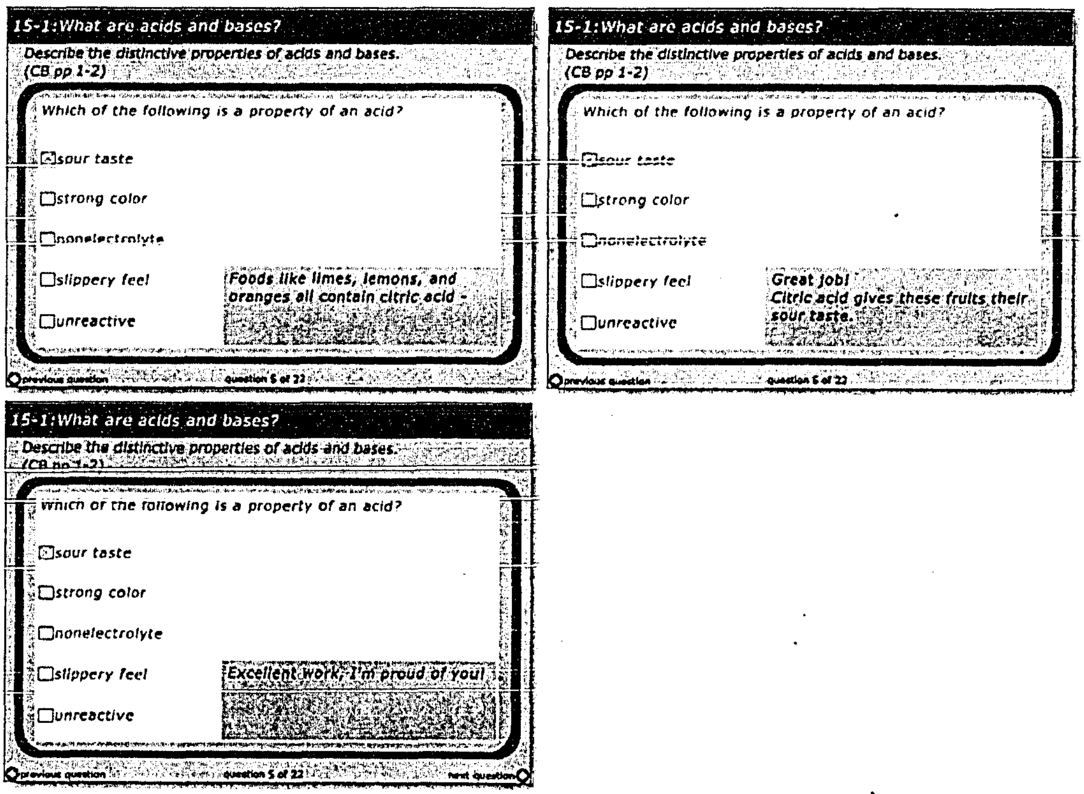

Figure 2.4 Example of KCR+ Feedback

Group E received captioned audio feedback for all answers, correct or incorrect. The incorrect answer feedback was individualized to the type of error that the student may have made, either conceptual or mathematical, which may have led him or her to choose that particular answer (topic contingent or response contingent). The correct answer feedback for group E participants was identical to that received by the group D participants (Figure 2.4). I have provided screen shots of the sequence of TC/RC feedback provided as text and audio for each of four possible incorrect responses in one question from a group E module (Figures 2.5-2.8).

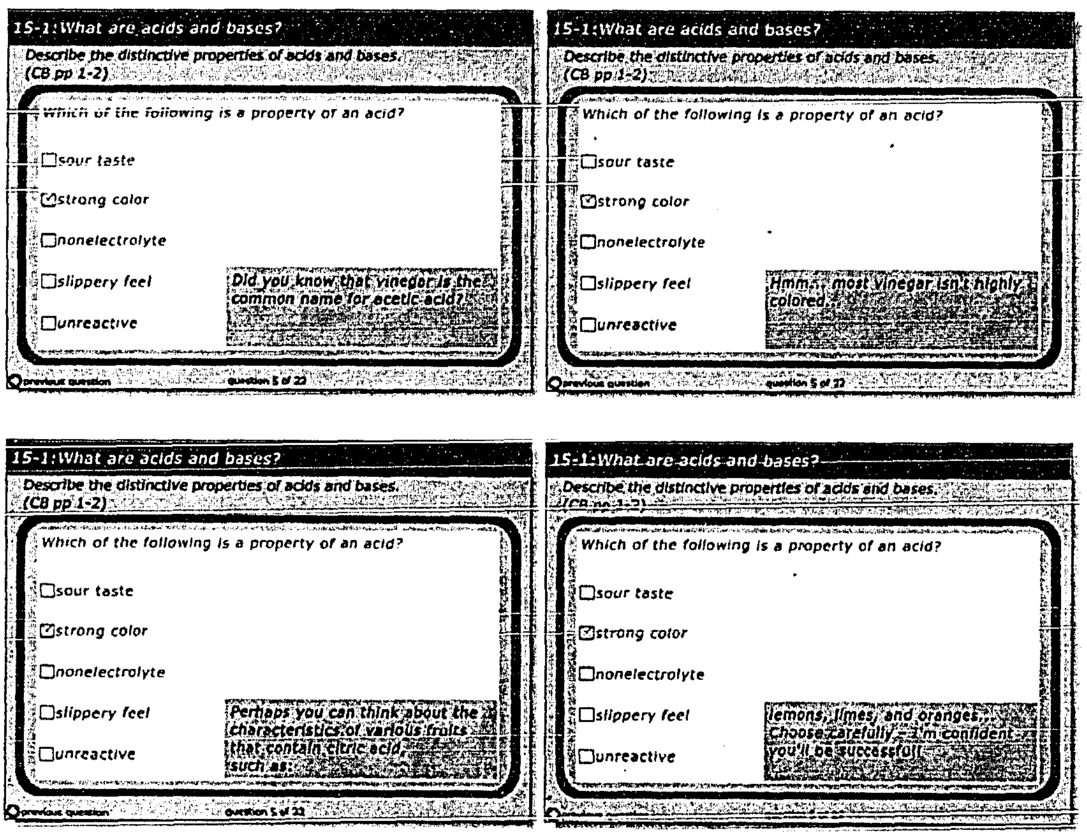

Figure 2.5 Example of TC/RC Feedback, 1 of 4

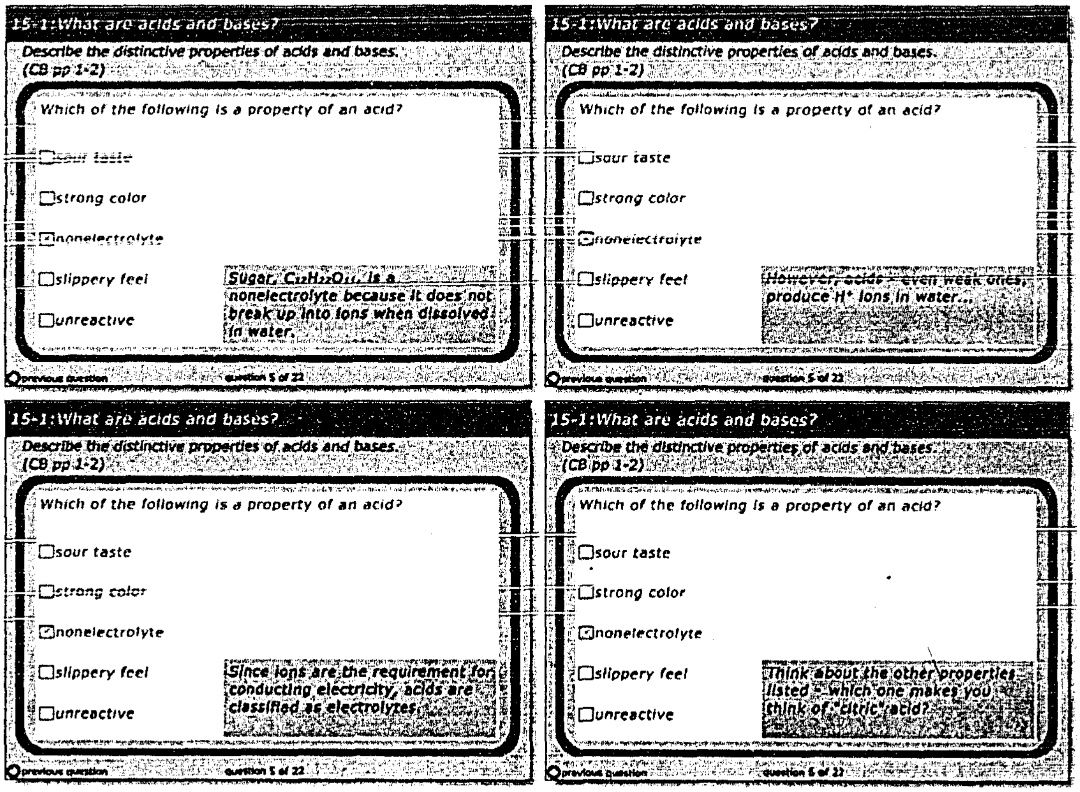

Figure 2.6 Example of TC/RC Feedback, 2 of 4

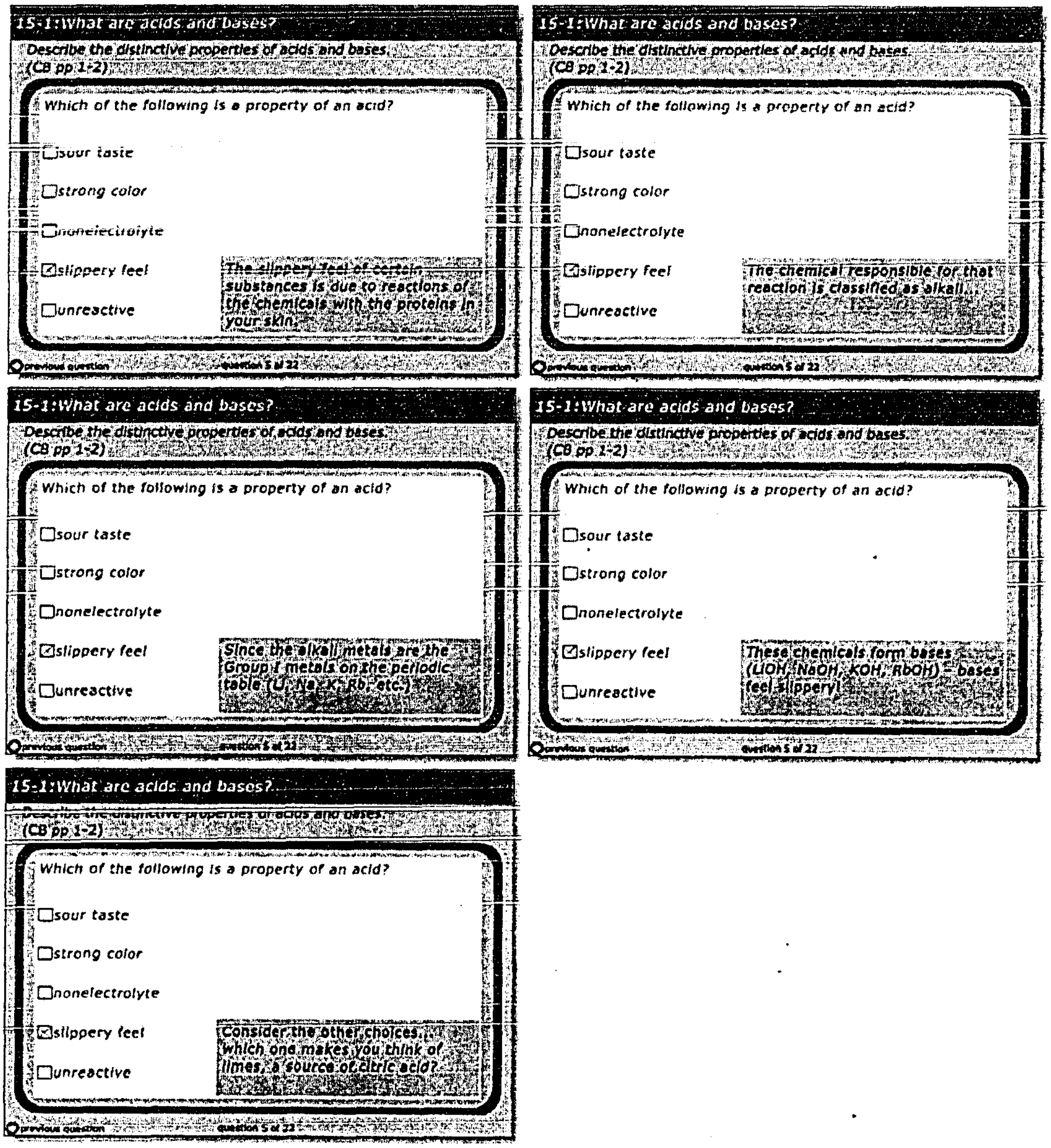

Figure 2.7 Example of TC/RC Feedback, 3 of 4

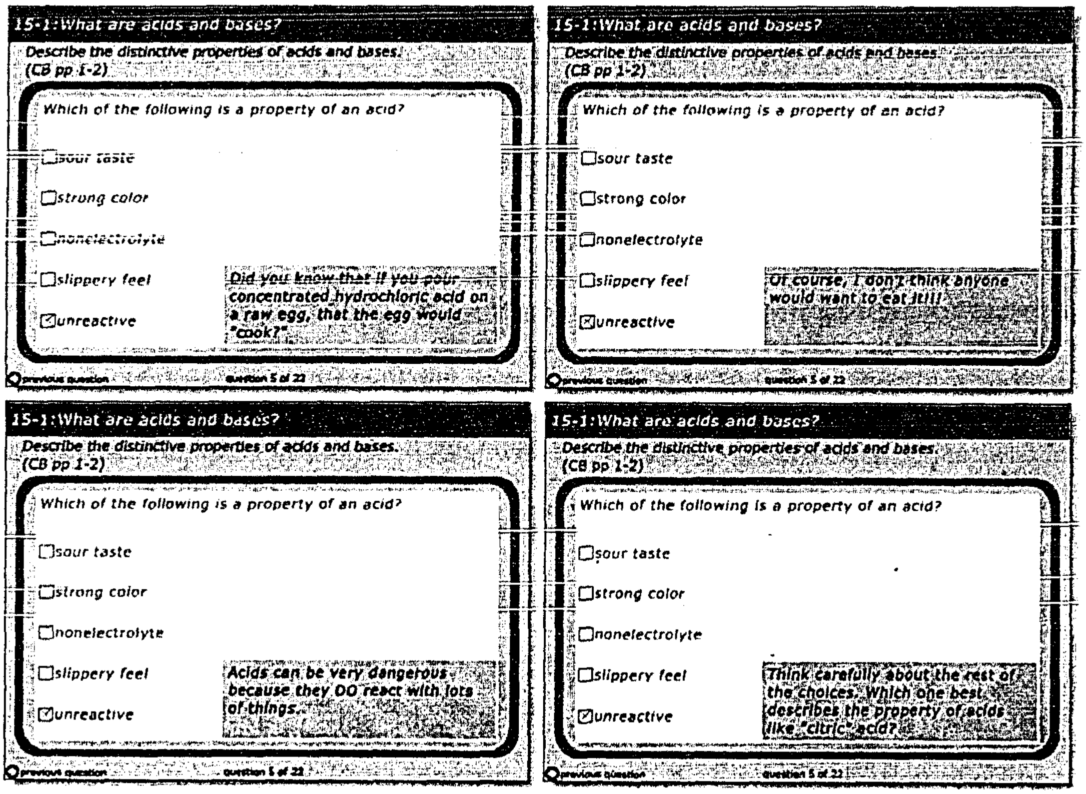

Figure 2.8 Example of TC/RC Feedback, 4 of 4

Dependent Variables

This study investigated two separate dependent variables: (a) level of science self-efficacy and (b) score on an objective-driven assessment. Science self-efficacy was assessed using the 48-item measure developed by Britner and Pajares (2001). The scale asked students to provide judgments along a six-point, Likert-type continuum. The questions addressed various facets of science self-efficacy beliefs such as science self-concept, self-efficacy for regulated learning, science anxiety, and the student's value beliefs for science education. This measure was used by other self-efficacy researchers (Britner & Pajares, 2001b; Pajares, Britner, & Valiante, 2000), and the Cronbach's alpha coefficient ranged from .79 to .81.

The second dependent variable, score on an objective-driven chemistry assessment, consisted of 60 multiple-choice questions. These questions were chosen from the textbook test software and were aligned to the textbook objectives and sub-objectives. Sample questions, aligned with the textbook objectives, are presented in Table 2.3.

Table 2.3 Sample questions from the objective-driven assessment

Objective 1.4: The pH of a solution is 9. What is its H_3O^+ concentration?

a. 10^{-6} M c. 10^{-3} M

b. 10^{-7} M d. 9 M

Objective 2.5: What is the acid-ionization constant, K_a, for the ionization of acetic acid, shown in the reaction $CH_3COOH(aq) + H_2O(l) \rightarrow H_3O^+(aq) + CH_3COO^-(aq)$?

a. $[H_3O^+][CH_3COOH^-]$ c. $\frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH]}$

b. $\frac{[H_3O^+][CH_3COO^-]}{[CH_3COOH][H_2O]}$ d. $\frac{[CH_3COOH]}{[H_3O^+][CH_3COO^-]}$

Objective 4.1: The substances produced when KOH(*aq*) neutralizes HCl(*aq*) are

a. HClO(*aq*) and KH(*aq*). c. $H_2O(l)$ and KCl(*aq*).

b. $KH_2O^+(aq)$ and $Cl^-(aq)$. d. $H_3O^+(aq)$ and KCl(*aq*).

I met with the four classroom teachers and we developed the daily class content, homework, laboratory experiments around these same objectives. This team of teachers was very accustomed to working closely together and it was a standard that all chemistry classes followed the same schedule and covered the same content in similar manners. Content validity was addressed by the use of expert reviewers. The measure was reviewed by a panel of three experts with an average of 9 years of chemistry teaching experience for accuracy and readability. They also evaluated the alignment of the questions to the textbook objectives, examined the balance of cognitive processes required, and verified the overall relevancy of the questions. Based on their expert judgment, revisions to several questions were made to improve the wording and balance of content. The final version of the measure was reviewed again, and the result was a 60-item measure that was broken down by objective (see Table 2.4). Table 2.5 separates the 60 ODA questions into their respective objectives and taxonomy level. The breakdown makes it obvious that the test represents the content and process objectives in proportion to their importance, a property of a test that is important for content validity.

Table 2.4 Breakdown of items according to textbook objectives

Textbook objective	Sub-objective	#
15-1: What are acids and bases? $N = 19$	15-1.1: Describe the distinctive properties of acids and bases	3
	15-1.2: Distinguish between the terms *strong* and *weak* as they apply to acids and bases	5
	15-1.3: Explain the unusually high electrical conductivities of acidic solutions	2
	15-1.4: Name and describe the functional groups that characterize organic acids and bases	1
	15-1.5: Use K_w to calculate a solution's hydronium ion or hydroxide ion concentration	8
15-2: Can the strengths of acids and bases be quantified? $N = 11$	15-2.1: State the Brønsted-Lowry definitions of an acid and a base	3
	15-2.2: Differentiate between monoprotic, diprotic, and triprotic acids	3
	15-2.3: Identify conjugate acid-base pairs	3
	15-2.4: Calculate Ka from the hydronium ion concentration of a weak acid solution	2
15-3: How are acidity and pH related? $N = 17$	15-3.1: State the definition of pH and explain the relationship between pH and H_3O^+ ion concentration	8
	15-3.2: Perform calculations using pH, $[H_3O^+]$, $[OH^-]$, and quantitative descriptions of aqueous solutions	7
	15-3.3: Describe two methods of measuring pH	2
15-4: What is a titration? $N = 13$	15-4.1: Write an ionic equation for a neutralization reaction, and identify its reactants and products	2
	15-4.2: Describe the conditions at the equivalence point in a titration	5
	15-4.3: Discuss two methods used to detect the equivalence point in a titration	1
	15-4.4: Calculate the unknown concentration of an acid or base using titration data	5

Table 2.5 A table of specifications for the ODA

Content Strata (Objectives/Topics)	Number of Questions at Each Taxonomy Level Knowledge	Higher	Total
15-1 What are acids and bases?	9 (1, 2, 5-7, 11-12, 14-15)	8 (3-4, 8-10, 13, 18-19)	17 28%
15-2 Can the strengths of acids and bases be quantified?	5 (20, 23, 24, 26-27)	6 (21-22, 25, 28, 29-30)	11 18%
15-3 How are acidity and pH related?	6 (31-32, 34-35,46-47)	13 (16-17, 33, 36-45)	19 32%
15-4 What is a titration?	6 (49-52, 54-55)	7 (48, 53, 56-60)	13 22%
Totals	26	34	60 100%

Note. Numerals in parentheses refer to specific items on the test

The reliability of this measure was addressed through an item analysis based on the protocol from Hopkins (1998) of the posttest ODA data from all participants. This analysis determined that certain questions yielded low item discrimination (*D*-index) values. Of the 60 items, five questions were discarded because they yielded a negative *D*-index value. Three other questions were examined because of their low *D*-index values; however, these items remained in the study. The decision to keep these three questions in the measure was based on the opinions of the expert panel. They unanimously agreed that the discarded items were ambiguously worded. However, the other three questions were described as *very difficult*; and they were not surprised that nearly all students, regardless of overall performance on the test, missed these questions. While they were not surprised at the outcome, they felt that the questions were fair and worded appropriately for the content that was covered in class. Therefore, of the 55 questions, three had a *D*-index value indicating poor item discrimination; 14 were labeled fair; 19 were labeled good; and the remaining 19 items, with *D*-index values over .40, had excellent discrimination. Because there is a direct relationship between item discrimination values and a test's internal consistency reliability, items with higher *D*-index values increase the instrument's reliability. Further, a corrected split-half reliability coefficient of 0.74 was calculated, indicating that the instrument was highly reliable (see Figure 2.9).

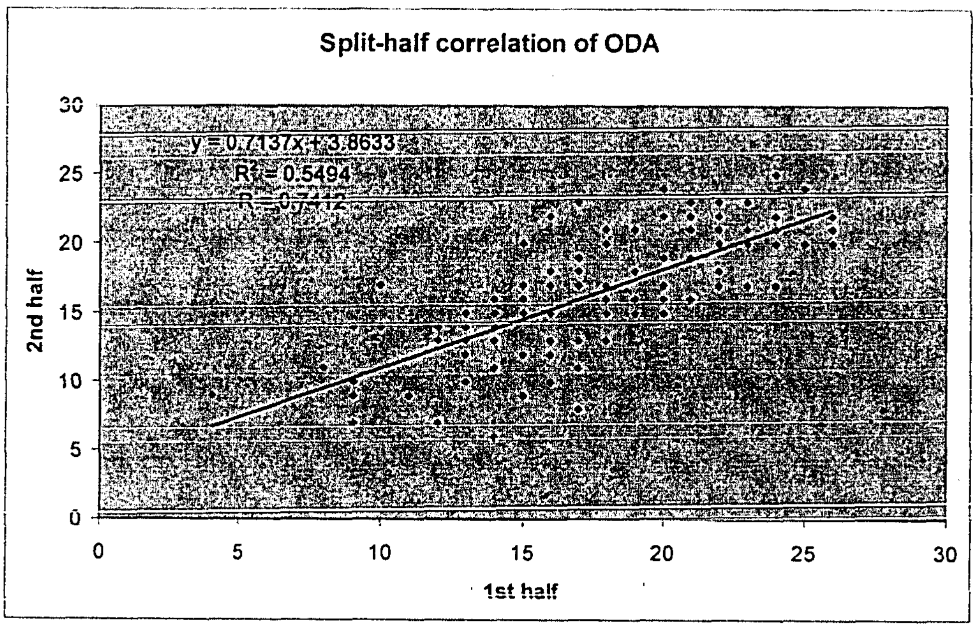

Figure 2.9 Split-Half Reliability Plot for the ODA

Data Collection and Analysis Procedures

Two days before the start of the study, I visited each class and introduced the study. According to the HSRC approval, the potential participants were made aware of the purpose of the study, the potential risks and benefits involved in participating, and the voluntary nature of the study. I also discussed the methods to maintain confidentiality, such as using a random nine-digit identification number and sealing the consent envelopes so that their teachers were unaware of which students were participating and which were not. I provided time for students to ask questions and then I distributed the informed consents, one for the student and one for her or his legal guardian, in envelopes for the students to take home, read, and return. As another layer of protection for confidentiality, I requested that all students turn in their sealed envelopes, regardless of whether or not the forms were signed. The envelopes were collected by the classroom teachers over the next several days until all envelopes from each class were accounted for. I collected the envelopes from the classroom teachers and compiled a master list of those students who had both forms signed. Data for the study only included the participants who gave full consent. The remaining students' data were not used.

I measured the dependent variables science self-efficacy (SSE) and academic achievement as both a pretest and a posttest. The classroom teachers administered the pretests on the first day of the unit before any in- or out-of-class learning of the content. They also administered the posttests on the last day of the unit, after all of the unit's objectives were addressed. To maintain confidentiality, all students, regardless of their status as participants, completed the pretests and posttests. This practice ensured that the students who did not give consent were anonymous to their classroom teacher, so there was no pressure from their teacher or peers to consent.

Students answered the questions on the SSE measure by circling the number that best matched their judgment for each equation. To maintain confidentiality, participants did not put their names on the SSE pretest or posttest; and all information was collected via their randomly assigned nine-digit identification number. To ensure that all questions were answered, students were reminded verbally and in writing to review all 48 items to verify that they had circled only one answer for every question and that no questions were left blank.

The pretest and posttest for the ODA was composed of only multiple-choice questions. Students were permitted to use scratch paper, a calculator, periodic table, and a pencil. All answers were recorded on a Scantron™, and the scratch paper was discarded. Students placed their name and identification number on the pretest and posttest Scantrons™. The results were machine scored against the master key. Unanswered questions were counted as incorrect.

Data Analysis Procedures

Two separate analysis of covariance tests were used to analyze the data (for a graphic depiction of the design, see Table 2.6). The random assignment of participants to one of three treatment groups was verified by performing a one-way analysis of variance on the pretest scores for the ODA and SSE measures, where ${}_{.95}F_{(2,107)} = 1.003$, $p = .370$ and ${}_{.95}F_{(2,107)} = .790$, $p = .457$, respectively. Because the random assignment of participants held true, the pretest was only included in the model to increase power. I present all quantitative findings and discuss their implications in chapter 4 of this dissertation.

Table 2.6 Graphic depiction of the experimental design

	Score on Dependent Variable	
	Pretest	Posttest
Group C		
Group D		
Group E		

Limitations

While this quantitative study has a very strong design, there are many threats to both internal and external validity. Furthermore, limitations in the form of weaknesses in the CAI module may have played a role in the results of the ANCOVAs reported. Threats to internal validity include (a) instrumentation, (b) testing, and (c) mortality. Instrumentation is a threat to the internal validity of the study because the participants knew that the pretest ODA did not influence their grade in the course. Therefore, some participants may have not tried their hardest to answer all questions on the pretest ODA to the best of their ability. Testing is a threat to internal validity because of the pretest/posttest design. As part of the qualitative data collection, the participants were asked a series of questions about their science self-efficacy and their experiences with the CAI modules. These questions may have changed the participants' attitude towards the treatment, possibly affecting the posttest results. Finally, of the original 113 participants that returned both consent forms, only 109 were kept for the study analysis. The other students were eliminated from the study due to multiple absences from their scheduled class period. This mortality rate is not severe, so this threat is of little consequence.

Threats to external validity include selection bias and pretest sensitization. Because this study was relatively small ($N = 109$) and because the sample came entirely from one suburban high school, the generalizability of the results to a larger population is weakened. Furthermore, because the participants in this study were exposed to a pretest of the concepts and the target population would most likely not have a pretest of the concepts, the target population might respond differently to the treatment.

Qualitative Analysis

I collected qualitative data from participants throughout the entire unit of study. The purpose of the qualitative data was to generate a better understanding of how feedback in CAI is related to both achievement and self-efficacy. The main research questions were subdivided into three more specific, yet still open-ended, qualitative questions: (a) How do students use different levels of feedback provided in computer-assisted instruction modules? and (b) How do different types of feedback affect how confident a student is in her or his ability to learn science? These questions were explored through a series of journal responses that the participants completed after each of the four CAI modules. The questions for each of the journals were focused on understanding each participant's perspective on the different facets of science self-efficacy, such as science anxiety, self-efficacy for self-regulated learning, and their judgments on the value of science. Each journal also asked at least one specific question about how the participant interacted with the CAI module and the feedback provided.

The majority of the journal questions were taken directly from the same SSE measure used in the quantitative study (Britner & Pajares, 2001). I chose to use these questions because they had already been established as relevant for understanding the different facets of science self-efficacy. Further, I wanted to gain more information about the underlying reasons for why students answered the Likert-type items in the way they did on the pretest and posttest. Examples of the journal questions taken from the SSE measure are found in Table 2.7.

Each journal response also included at least one specific question on how the learner processed the feedback provided during the module they just completed. I developed these questions with then intent to understand not only if but also how the feedback was being mindfully processed by the learners. Sample questions can be found in Table 2.8. The full set of journal questions for all four modules are in Appendices G-J.

Table 2.7 Sample journal questions from the SSE measure

1.	*Please describe your confidence in your ability to pass science class at the end of the semester.* What grade do you think you will earn? What are your strengths? What are your weaknesses?
2.	*Please describe how well you are able to study when there are other interesting things to do.* What conditions are best for your learning? What conditions are worst for your learning?
3.	*Please describe what your "ideal" environment is for learning.* For example, do you learn best through classroom discussions, reading alone, study groups with your peers, one-on-one interaction with your teacher, using a computer for research and/or practice, etc. Please feel free to mention another environment that I did not just list.
4.	*How well can you motivate yourself to do schoolwork? What* role(s) do your parent(s)/guardian(s), friends, and teachers play in helping you get your work completed?

Table 2.8 Sample journal questions about the CAI modules

Describe your initial reaction to the computer module you just completed. Were there any features of the tutorial that helped you learn? Were there things that you liked or disliked? In your response to this question, please think about how you responded to the other questions in this journal – are there any connections that you see between how you described yourself as a learner and how you felt about this particular computer learning experience?
Now, thinking about the 2^{nd} module that you just completed, please reflect on the following statement. Is it true, false, or somewhere in between? *Why do you feel this way?*\
Using a computer to review helps me feel more confident that I will do better on future examinations.

At the conclusion of the study, I purposefully selected several students to participate in a follow-up interview to both triangulate the journal and quantitative findings as well as to provide the researcher with an opportunity to explore further certain facets of the CAI learning experience.

Overall Approach and Rationale

Because the goal of the qualitative portion of this study was to understand better the phenomenon of how feedback is used in CAI and whether or not different types of feedback influence learners' level of academic achievement and science self-efficacy, I used a phenomenological approach to generating the questions, analyzing the data, and reporting the findings (Creswell, 1998). The origins of this discipline are in philosophy, sociology, and psychology because the intent is to "understand the essence of experiences about a phenomenon" (p. 65). I analyzed the data to find significant statements and meanings to generate themes and general descriptions of the experiences of the learners in CAI modules. From this analysis, I developed a description of the essence of the experience to help explain the quantitative findings and generate a broader understanding of how feedback is best presented in CAI.

Site and Population Selection

Because the qualitative data collection occurred concurrently with the quantitative data collection, the site and population selection for the qualitative portion of this study is almost identical to that in the quantitative portion. The only exception is that, at the conclusion of the study, I purposefully selected eight participants to complete a follow-up interview. Of the eight, six consented to participate in a follow-up interview with me about their experiences and perceptions during the 3-week unit. I selected these students using both stratified purposeful and extreme or deviant case purposeful sampling strategies. I identified students from each group who, based on their journal entries, could facilitate comparisons between the subgroups (i.e., stratified purposeful). Additionally, I identified students as possible interview participants based on their journal entries that set them apart from the rest of the group because of their extreme like or dislike of the CAI modules (i.e., extreme or deviant case). In summary, I collected journal data from all participants and interview data from six purposefully selected participants.

Researcher's Role

As the researcher, I chose to perform this study at the same school where I currently teach. However, I did not use my own students; so, I needed to establish a rapport with the participants and explain why I was interested in having their help. This rapport was essential to the qualitative portion of the study because of the personal nature of the journal questions. I felt strongly that the participants would need a reason to answer questions such as "Sometimes I get so nervous in science that even though I think I know something, I can't remember it when I need it." The participants were asked to state whether this statement was true or false and, then, to describe why he or she felt that way. If the participants did not know about my background and why I was interested in their answers to these types of questions, I feared that they would not take the time to answer the journal questions honestly and thoroughly.

I addressed each class to introduce the study and distributed the informed consent letters. At this time, I deliberately attempted to identify myself as a student; and, like them, I had homework. I also emphasized the fact that having their help with this research project would help me understand how students learn best. This introduction was made with the intent of gaining access to more students for the study. I hoped that by being upfront with them about what I was doing and why and by emphasizing what I hoped to learn from the research, that more students would be interested in participating and providing meaningful data in the form of thoughtful journal entries.

Additionally, I was very careful to emphasize how I would maintain confidentiality by using random identification numbers. Because many of the journal questions asked the participants to discuss their feelings about themselves in terms of their confidence to complete certain tasks or how they felt about their individual abilities to learn, I wanted to make sure that the participants felt safe to tell me the truth without fear of having others read their responses. In the written directions for each journal response, I reiterated my promise to keep their responses confidential; and they only identified themselves by their assigned identification number, not by name. Also, as I read and coded the journal responses, I did not match names with identification numbers until I had isolated the eight individuals that I wanted to ask for a follow-up interview.

To gain access to the individuals selected for follow-up interviews, I requested their participation in writing. To acknowledge their willingness to participate, the written invitation asked them to sign their name to the slip and return it to their classroom teacher. The instructions clearly stated that their participation was optional, and there would be no penalty if they chose to not consent.

Data Collection Methods

Students completed and submitted journal responses via the Web immediately following each of the four CAI modules completed over a 3-week period. In the directions, I asked students to respond to each question with 2 to 3 sentences, and not worry about formatting their responses for correct spelling or grammar. The first journal contained five questions and immediately followed the completion of the first module. Four of the questions were designed to explore the participants' self-efficacy for self-regulation. These questions were similar to the items on the SSE measure used in the quantitative portion of the study. One additional question asked the participants to describe their initial impressions of the CAI module as a learning experience.

The second journal contained six questions, five of which were from the SSE measure designed to explore the participants' science self-concept (i.e., how they judge their self-worth associated with their self-perception as a science student). An additional question asked the participants to discuss how using a computer for review affects their confidence to perform better on future examinations. The third journal, composed of seven questions, emphasized science anxiety using five similarly worded questions as the SSE measure. The final two questions also addressed science anxiety but from the context of how using a computer affected their anxiety levels. The final journal, following the fourth CAI module, was composed of five questions asking the participants to describe how they used the feedback in the CAI modules. Complete copies of all journal questions can be found in Appendices G-J.

Of the eight students that I asked to participate in the follow up interviews, three were in Group C, three were in group D, and two were in group E. Of the final six that gave consent, three were in Group C, two were in group D, and one was in group E. I conducted the interviews during the participants' normally scheduled class time in the week following the posttests. Prior to the interview, I gave the interviewees a list of the general questions that I would ask. The interviews took place in the privacy of my office at the school or in an empty classroom. I recorded the entire dialogue on my laptop and saved it onto a compact disc. Occasionally, I asked students to clarify their previous statement, or I asked an additional question to better understand the meaning of their previous statements.

Data Management Procedures

Students submitted each journal response electronically to my private email account via a Web-based form. For identification purposes, I asked participants to give their 9-digit number at the start of each form. I combined all responses into one large Excel document, separated by journal and group so that all the group C responses for the first journal could be read from one worksheet, all the group D responses for the first journal could be read on a second worksheet, and so on.

I transcribed interviews from the audio recordings and I included my observational notes from the sessions. Observational notes included information on the setting, the body language of the interviewee, and other notes such as the school bell ringing in the middle of the interview. I tried to generate a verbatim transcript, but occasionally the recording was insufficient to clearly understand the words spoken. I noted these instances in the observational notes column.

Data Analysis Procedures

I subjected the journal entries and the interview transcriptions to the four-step Colaizzi (1978) method referenced by Creswell (1998). (a) I read all subjects' journal entries and the interview transcriptions in order to get the general feeling for the different themes that may emerge. (b) I noted significant statements from multiple entries, the statements were considered significant if they directly related to the phenomena, feedback and science self-efficacy. (c) Next, I extracted and summarized meanings from the significant statements summarized. (d) Finally, I identified the themes and organized them according to categories. I determined significance by comparing the statements to accepted models of feedback processing (Bangert-Drowns et al., 1991; Mory, 2004) or common themes from the development of self-efficacy (Bandura, 1997; Schunk & Pajares, 2001).

Summary

In this chapter, I outlined the quantitative and qualitative methods use for this study. The quantitative design used a true experimental approach with three different treatment groups. The treatment was composed of different types of feedback provided in CAI modules the participants used during a three-week unit in their high school chemistry class. The dependent variables measured science self-efficacy and academic achievement. The science self-efficacy measure was a 48-item Likert-type measure developed by Britner and Pajares (2001). Academic achievement was measured using a 60-item objective-driven assessment of the chemistry concepts covered in the three-week unit. I measured both dependent variables as a pretest and posttest. The purpose of the pretest data was to ensure the random assignment of participants to treatment groups. Later, I used the pretest as a covariate in the quantitative analysis to increase the power of the test. I collected qualitative data in the form of journal entries and interviews. These data were collected, organized, and analyzed using the concurrent triangulation methods described by Creswell (1998, 2003) in an attempt to add meaning to the interpretation of the quantitative results.

In the next two chapters, I present my findings and interpretations of the quantitative (chapter 3) and qualitative (chapter 4) data. For these two chapters, I treat the data separately. Then, in chapter 5, I tie the two methods together to show how the results converge to create a more complete understanding of how feedback provided in computer-assisted instructional modules, science self-efficacy, and academic achievement are related. Chapter 5 also outlines my recommendations for future research and design recommendations for creating CAI that maximizes the use of feedback to promote academic achievement.

CHAPTER 3

A SUMMARY OF THE QUANTITATIVE ANALYSES AND PRESENTATION OF THE FINDINGS

The overarching questions I address in this study are (a) How does feedback in chemistry CAI affect students' levels of science self-efficacy? and (b) How does feedback in science CAI affect student achievement on an objective-driven assessment? I narrowed these questions for the sake of clarity, specificity, feasibility, and importance to include: (a) Do different types of feedback in science CAI, namely KOR, KCR, KCR+, topic contingent, and response contingent, affect learners' levels of science self-efficacy? (b) Do different types of feedback in science CAI, namely KOR, KCR, KCR+, topic contingent, and response contingent, affect learners' scores on an objective-driven science assessment? (c) How do learners use different levels of feedback provided in science CAI modules? and (d) How do different types of feedback affect how confident a learner is in her or his ability to understand science? I addressed the first two questions using quantitative methods. This chapter is dedicated to the interpretation and analysis of those results.

A Review of the Quantitative Study Design, Method, and Hypotheses

I performed this study over the course of a three-week chemistry unit and study participants were all students enrolled in general chemistry at a suburban high school in Aurora, Colorado. During the unit, the chemistry classes visited the school's computer lab four times. The quantitative portion of the mixed-methods design for this study included one independent and two dependent variables. The independent variable had three levels. During the visits to the computer lab, participants completed four CAI modules that delivered multiple-choice style questions aligned to the chemistry unit objectives. Participants in the first level of the independent variable, group C, received knowledge of response (KOR) and knowledge of correct response (KCR) feedback. Group D participants received KOR and knowledge of correct response plus elaboration (KCR+). Group E participants received KOR, KCR+, and topic contingent and response contingent (TC/RC) feedback.

The dependent variables I investigated were academic achievement and science self-efficacy (SSE). I quantified academic achievement by administering an objective-driven assessment (ODA) of the chemistry objectives that accompanied the unit of instruction (see Appendix E). I measured the second dependent variable, SSE, with a 48-item Likert-type self-report questionnaire designed by Britner and Pajares (2001) to measure science self-efficacy (see Appendix F). The data for both measures were entered into an Excel workbook and later imported into SPSS for the statistical analyses. Validity and reliability information for each measure indicated that they both not only measured what they purported to measure, but they also did so with a high degree of consistency. I provided a thorough description of each test in chapter 2 of this dissertation.

Analysis of Covariance

I chose to use an analysis of covariance (ANCOVA) model as the statistical tool to analyze the quantitative data from the SSE and ODA measures. I chose the ANCOVA over the repeated measures analysis of variance (RM-ANOVA) for several reasons, all of which are well documented by statisticians over the last several decades (Bonate, 2000; Huck & McLean, 1975; Jennings, 1988). The underlying linear model for the RM-ANOVA design is not completely sound because the pretest scores were collected prior to the treatment. This is a problem because it is impossible for the treatment effects or an interaction effect to affect the pretest scores. The linear model, however, assumes that all measurements are made after the treatment. Therefore, it is inappropriate to use the RM-ANOVA design to analyze pretest and posttest data.

The ANCOVA model is a combination of regression and analysis of variance. The pretest data act as a type of statistical control because the model uses the pretest scores to adjust the posttest scores in a way that makes all of the pretest scores appear to have the same baseline. The covariate serves several functions. It is used to (a) reduce error variance, (b) consider any preexisting mean group difference on the covariate, (c) consider the relationship between the covariate and the dependent variable, and (d) yield a more precise and less biased estimate of the group effects. The assumptions of the ANCOVA are (a) random and independent errors,

(b) homogeneity of variance, (c) normality, (d) linearity, (e) fixed independent variable, (f) covariate measured without error, and (g) homogeneity of regression slopes (Lomax, 1992). Each of these assumptions can be tested to ensure that they are not violated and I exhaustively test each later in this chapter, immediately following the presentation of the ANCOVA results for each measure.

I tested two similar hypotheses with the ANCOVAs of the ODA and SSE data. Both hypotheses compared the adjusted group means on the measures of the dependent variables. The null hypothesis for the ODA measure was, in the population, there is no difference in adjusted posttest means on the ODA between treatment groups. Similarly, the null hypothesis for the SSE measure was, in the population, there is no difference in adjusted posttest means on the SSE between treatment groups.

First Dependent Variable, Posttest Scores on an Objective-Driven Assessment

I measured academic achievement using an ODA, composed of multiple-choice style questions aligned to the various chemistry objectives for the unit on acids and bases. An ANCOVA analysis, with the pretest as the covariate, did not reveal any significant differences between the treatment groups on the adjusted posttest means ($_{.95}F_{(2, 106)} = 1.311, p = 0.274$). Summaries of the unadjusted posttest means, adjusted posttest means, and the ANCOVA results are presented in Table 3.1, Table 3.2, and Table 3.3, respectively. Thus, the results failed to reject the null hypothesis that were no significant differences between the adjusted means on the ODA between the three different treatment groups.

Table 3.1 Summary of unadjusted posttest means for the ODA

Group	Mean	Std. Deviation	*N*
Group C	31.13	8.370	39
Group D	33.83	8.169	35
Group E	32.64	8.472	36
Total	32.48	8.339	110

Table 3.2 Summary of adjusted posttest means for the ODA

				95% Confidence Interval	
Group	*N*	Mean	Std. Error	Lower Bound	Upper Bound
Group C	39	30.852[a]	1.262	28.349	33.355
Group D	35	33.566[a]	1.332	30.925	36.207
Group E	36	33.193[a]	1.320	30.576	35.810

[a]Covariates appearing in the model are evaluated at the following values: PRETEST = 17.77.

Table 3.3 ANCOVA summary table for the ODA

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.
Adjusted Between	162.400	2	81.200	1.311	.274
Adjusted Within	7579.464	106	61.947		
Covariate	877.298	1	877.298	14.162	.000
Corrected Total	7579.464	109			

Testing the Assumptions of the ANCOVA Model for the ODA Measure

Using SPSS and Excel, I tested the assumptions of the ANCOVA model to ensure that they were not violated, thereby voiding the interpretation of the results. No assumptions were violated for the ODA ANCOVA. The first assumption, random and independent errors, was tested by generating three residual plots, one per treatment group (see Figure 3.1, Figure 3.2, and Figure 3.3). All three plots appeared to be random; thus, I concluded that the first assumption of the ANCOVA was met.

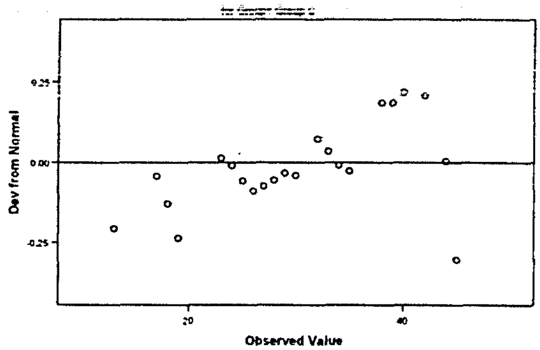

Figure 3.1 Residual Plot for Group C, ODA Measure

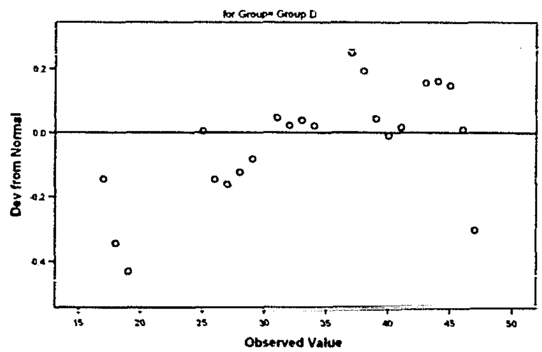

Figure 3.2 Residual Plot for Group D, ODA Measure

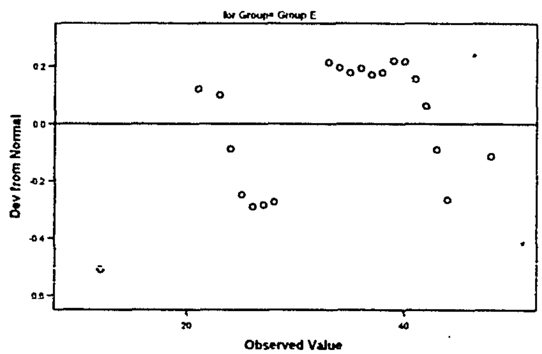

Figure 3.3 Residual Plot for Group E, ODA Measure

The second assumption, homogeneity of variance, was assessed using Levene's Test of Equality of Error Variances, which tests the null hypothesis that the error variance of the dependent variable is equal across groups. Based on the p-value from this test ($_{.95}F_{(2, 107)} = .483$, $p = .618$), I failed to reject this null hypothesis. Therefore, the assumption of homogeneity of variance was met.

I tested the third assumption, normality, by examining the three normal quartile plots, one per treatment group (Figure 3.4, Figure 3.5, and Figure 3.6). These plots all show that the data follow a normal plot because of their straight-line nature. Thus, the assumption of normality was met.

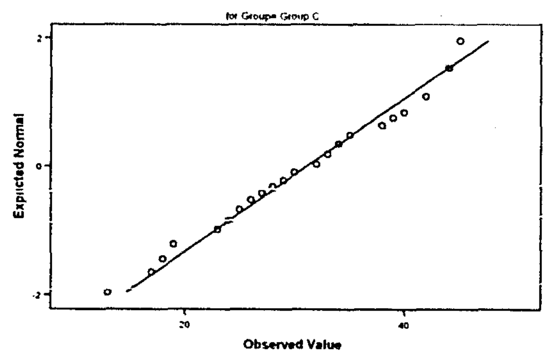

Figure 3.4 Normal Quartile Plot for Group C, ODA Measure

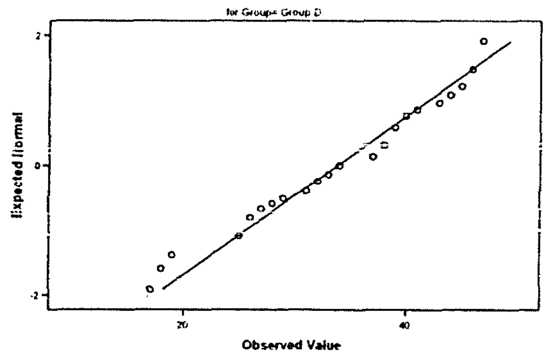

Figure 3.5 Normal Quartile Plot for Group D, ODA Measure

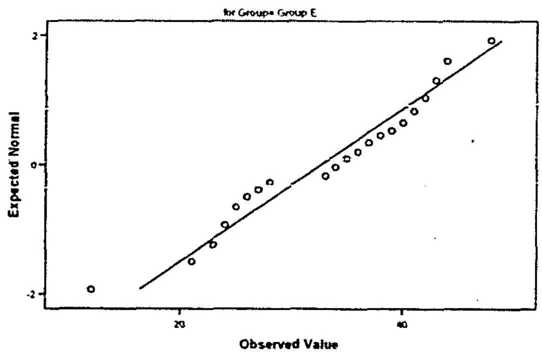

Figure 3.6 Normal Quartile Plot for Group E, ODA Measure

The fourth assumption, linearity, was also not violated. Figure 3.7 shows the scatterplot and linear regression line for each group's pretest and posttest scores. The relationships are more linear than curved, thus the assumption of linearity was met. The fifth and sixth assumptions were both met due to the nature of the pretest/posttest design. Finally, the last assumption, homogeneity of regression slopes, was not violated because an ANCOVA with the inclusion of a term for the group by pretest interaction revealed no significant interaction, $p = 0.528$ (see Table 3.4).

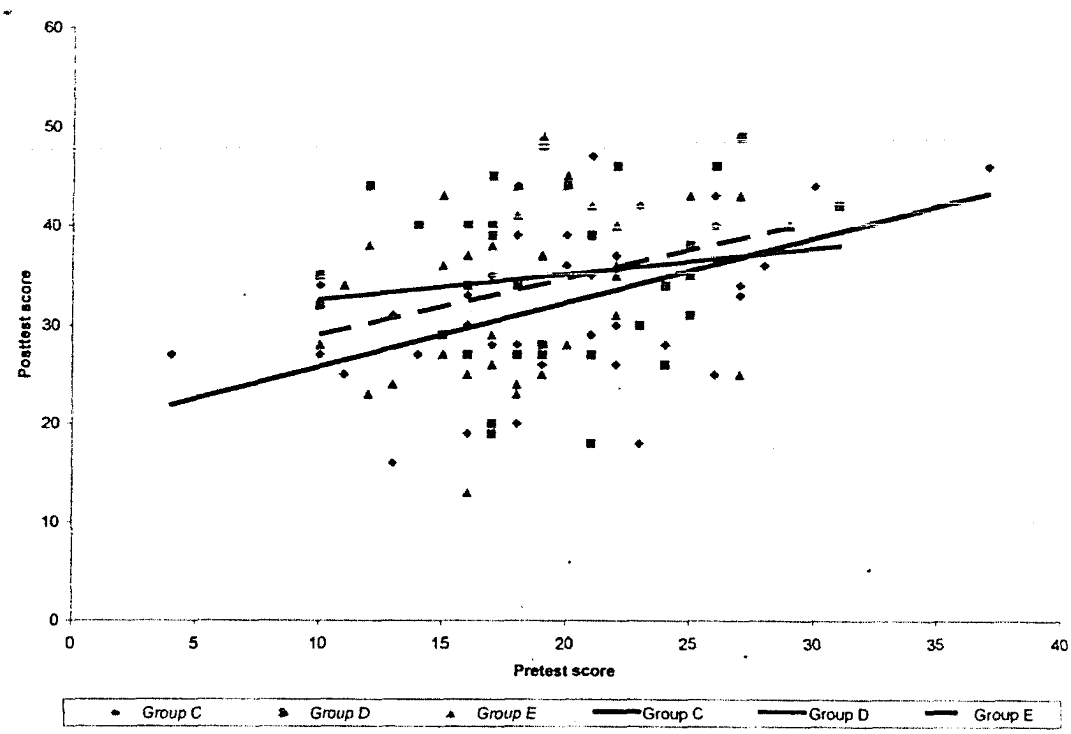

Figure 3.7 Correlation of the Pretest and Posttest Scores by Group

Table 3.4 ANCOVA with group by pretest interaction

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.
Corrected Model	1093.165[a]	5	218.633	3.506	.006
Intercept	4497.420	1	4497.420	72.111	.000
Group	142.164	2	71.082	1.140	.324
PRETEST	671.068	1	671.068	10.760	.001
Group * PRETEST	80.039	2	40.020	.642	.528
Error	6486.299	104	62.368		
Total	123637.000	110			
Corrected Total	7579.464	109			

[a]R Squared = .144 (Adjusted R Squared = .103)

Second Dependent Variable, Posttest Scores on a Measure of Science Self-Efficacy

I measured science self-efficacy using a 48-item instrument developed by Britner and Pajares (2001a). For both the pretest and the posttest, students responded on a Likert-type scale to various questions about their science self-efficacy. After reversing the negatively worded items, a total score was calculated for each participant. The results were then analyzed using an ANCOVA. Descriptive statistics and results are shown in Tables 3.5, 3.6, and 3.7. Again, no significant difference was observed for the posttest data, with pretest as the covariate, by treatment group ($_{.95}F_{(2, 106)} = 1.080$, $p = 0.344$).

Table 3.5 Summary of unadjusted posttest means for the SSE measure

GROUP	Mean	Std. Deviation	*N*
Group C	186.87	35.451	39
Group D	188.99	33.868	35
Group E	195.86	32.095	36
Total	190.49	33.788	110

Table 3.6 Summary of adjusted posttest means for SSE measure

			95% Confidence Interval	
GROUP	Mean	Std. Error	Lower Bound	Upper Bound
Group C	189.039[a]	2.363	184.354	193.724
Group D	191.946[a]	2.496	186.997	196.894
Group E	190.636[a]	2.469	185.740	195.531

[a]Covariates appearing in the model are evaluated at the following values: PRETEST = 193.82.

Table 3.7 ANCOVA summary table for the SSE measure

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.
Adjusted Between	157.031	2	78.515	.361	.698
Adjusted Within	23043.444	106	217.391		
Covariate	99767.464	1	99767.464	458.931	.000
Corrected Total	124439.230	109			

Testing the Assumptions of the ANCOVA Model for the SSE Measure

I tested ANCOVA assumptions to ensure that the SSE data met the various requirements for this analysis. The assumptions tests are the same as previously described for the ODA measure in the previous section of this chapter. Thus, I only summarize each test's results. The first five assumptions were all met with the following justifications (a) random and independent errors, evidenced by the random appearance of the three residual plots (see Figures 3.8-3.10); (b) homogeneity of variance, Levene's test $p > \alpha$ ($_{.05}F_{(2, 107)} = .987, p = .377$); (c) normality, normal quartile plots show that the data follow a normal plot (see Figures 3.11-3.13); (d) linearity, scatterplot of pretest and posttest scores are more linear than curved (see Figure 3.14); (e) fixed independent variable, I set the levels of the independent variable; and (f) covariate measured without error, the systematic and random error associated with the pretest is also associated with the posttest, because they are the same measure.

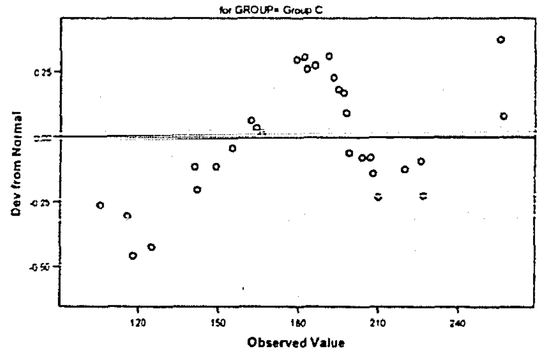

Figure 3.8 Residual Plot for Group C, SSE Measure

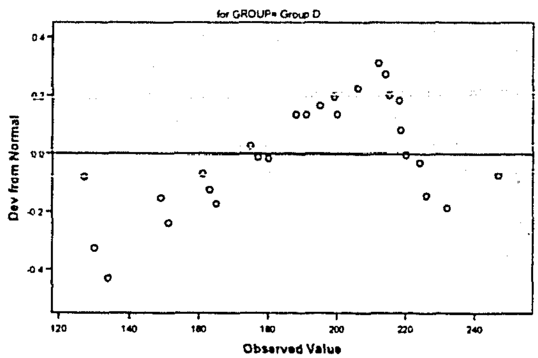

Figure 3.9 Residual Plot for Group D, SSE Measure

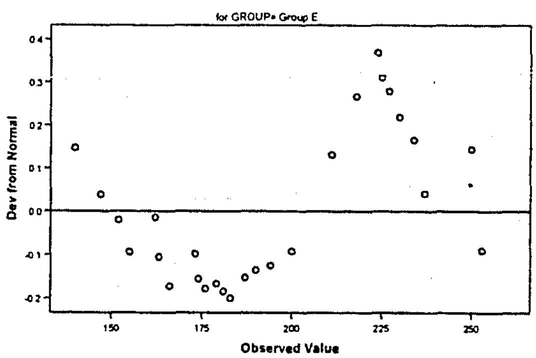

Figure 3.10 Residual Plot for Group E, SSE Measure

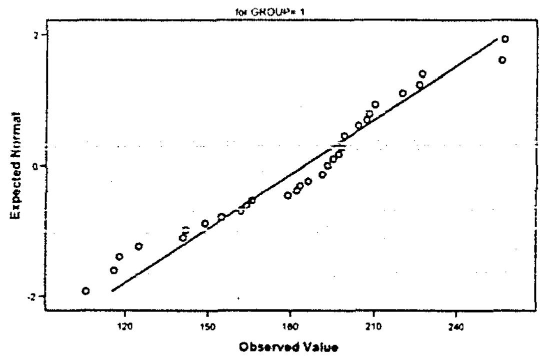

Figure 3.11 Normal Quartile Plot for Group C, SSE Measure

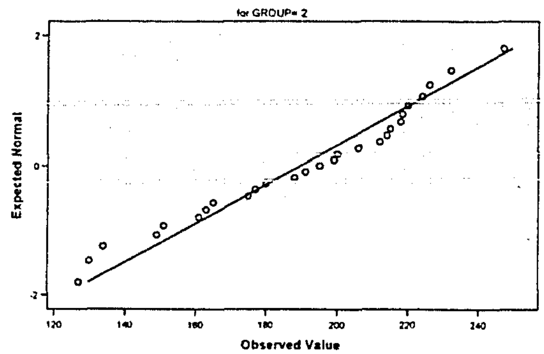

Figure 3.12 Normal Quartile Plot for Group D, SSE Measure

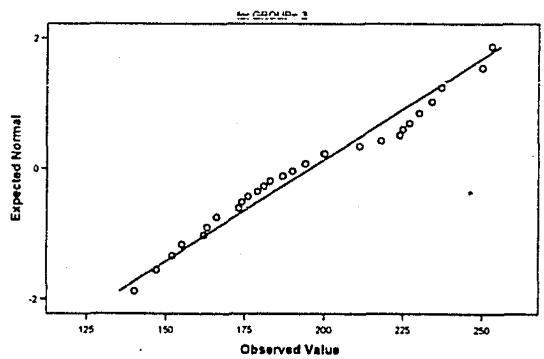

Figure 3.13 Normal Quartile Plot for Group E, SSE Measure

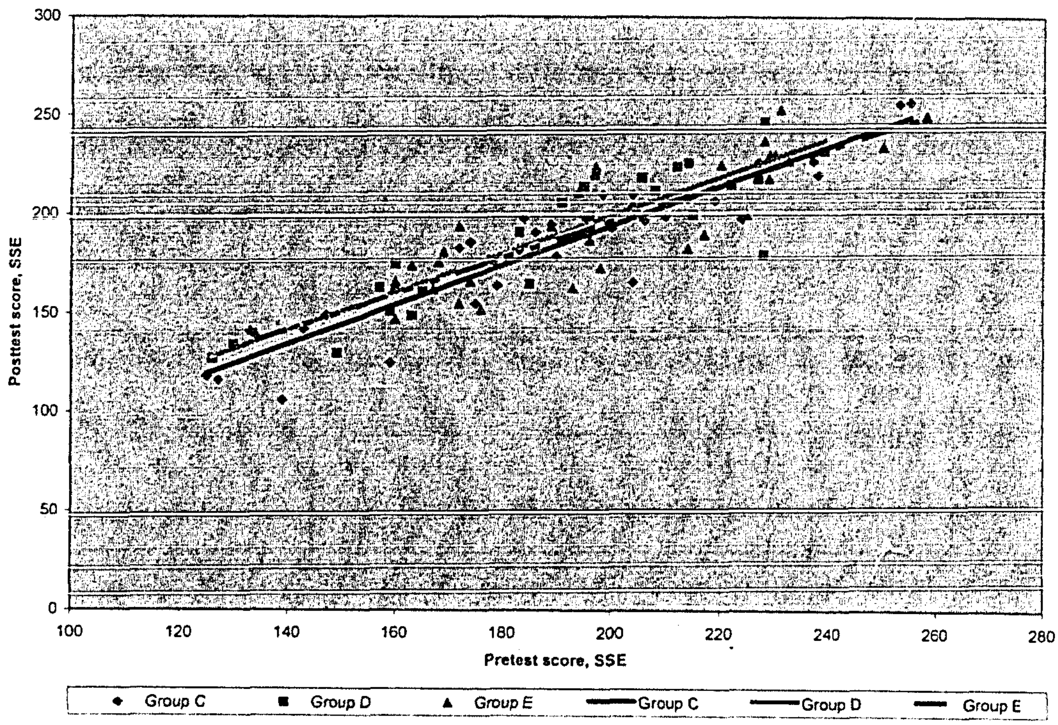

Figure 3.14 Correlation of the Pretest and Posttest Scores by Group, SSE Measure

The last assumption, homogeneity of regression slopes, was violated because an ANCOVA with the inclusion of a term for the group by pretest interaction revealed a significant interaction, $p < .05$ (see Figure 3.14). Violation of the homogeneity of regression coefficients assumption indicates the possibility of unequal treatment effects between the three groups. However, because no significant difference between the adjusted SSE posttest means were found, the violation of this assumption does not critically change the interpretation of the data. A one-way ANOVA test was performed on the unadjusted SSE posttest means as a cautionary measure to ensure that the results did not achieve significance (this assumption is not included in an ANOVA). No significant differences were observed from this additional test ($_{.95}F_{(2, 170)} = .709, p = .494$).

Table 3.8 Group by SSE pretest interaction

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.
Corrected Model	101368.968[a]	3	33789.656	155.252	.000
Intercept	23.730	1	23.730	.109	.742
GROUP * PRE_SSE_SUM	101368.968	3	33789.656	155.252	.000
Error	23070.262	106	217.644		
Total	4115795.250	110			
Corrected Total	124439.230	109			

[a]R Squared = .815 (Adjusted R Squared = .809)

Overall Summary of the Quantitative Results

The findings of the ODA and SSE ANCOVAs did not support the rejection of either null hypothesis. Thus, there was not enough evidence to support the assertion that students receiving different levels of feedback during CAI experiences would have significantly different adjusted posttest means on the ODA and SSE measures. These results were similar to those I attained in both pilot studies leading to this study. Thus, I was not surprised to observe no statistically significant differences between the groups; however, I was disappointed. I genuinely thought the modifications from the pilot study would result in statistical differences between the groups because I felt that the overall design of the study was sound and that the feedback differences between the three groups would be vast enough to facilitate the groups with more feedback to outperform the group with limited feedback. Fortunately, I gathered qualitative data, as well. In the next chapter, I attempt to use the qualitative data to understand why no significant differences were observed quantitatively.

CHAPTER 4

QUALITATIVE ANALYSIS AND INTERPRETATION

The quantitative portion of this study was limited to the two pretest/posttest measures; however, I also collected qualitative data throughout the study in the form of four journal responses and six follow-up interviews with purposefully selected participants. The purpose of the qualitative data was to generate a better understanding of how feedback in CAI is related to both achievement and self-efficacy. To this end, I subdivided the main research questions into two more specific, yet still open-ended, qualitative questions: How do students use different levels of feedback provided in computer assisted instruction modules? and How do different types of feedback affect how confident a student is in her or his ability to learn science? I explored these two questions through a series of journal responses that the participants completed after each of the four CAI modules. The questions for each of the journals focused on understanding the participants' perspectives on the different facets of science self-efficacy (see Appendices G-J). The questions pertaining to science self-efficacy were taken directly from the measure designed by Britner and Pajares (2001). In each journal, I also asked at least one specific question about how the participant interacted with the CAI module and the feedback provided. I tested these questions during the pilot study. At the conclusion of the study, I purposefully selected several students to participate in a follow-up interview to triangulate my interpretations from the journal.

To analyze the data, I began by identifying the common themes present in the responses. These themes focused on how students used the feedback provided in the different modules. In particular, I was interested in understanding how the feedback affected the students' ability to understand the science concepts presented; which, presumably, would also affect the students' confidence to answer future questions correctly. In this chapter, I identify the major themes from the journal responses. Then, I present a summary of these statements. From these statements, I generated a textual description of the types of learners, accompanied by selected examples, and my interpretation of how these themes may have been the underlying reasons for why no significant differences between the three groups on either measure was observed in the quantitative portion of this study.

Identification of Themes

I began by reading through all of the journal responses to develop a broad understanding of the responses to the four sets of journal questions. I was not surprised when it became obvious that the students either really liked or really disliked the CAI module approach. While there were a few students who expressed neutral feelings about using the modules, most students very clearly stated their preferences. Equally unsurprising was that the students who professed a preference for the modules also tended to be more willing to pay attention to the feedback and make a concerted effort to answer the questions correctly. In contrast, students who disliked the modules often confessed that they guessed during the questions and did not listen to the feedback.

Consequently, the first theme that emerged from the journal responses was broadly identified as *preference for CAI modules*. I separated this theme into three categories, (a) positive, (b) negative, and (c) ambivalent or neutral. I read all journal responses and classified the participants into one of these categories based on all four of their journals. When I calculated the percentages based on the number of participants in each group, I found it interesting to note the similarities between the three treatment groups, especially for the percent of participants who expressed a positive preference for using the CAI modules for learning (see Table 4.1). Across all groups, approximately two-thirds of all participants liked using the modules.

Table 4.1 Preference for CAI modules

	Positive	Negative	Ambivalent or neutral
Group C	68%	8%	24%
Group D	65%	19%	16%
Group E	66%	9%	25%
Overall	66%	12%	16%

Note. Percentages were calculated after each participant's journal entries were read and categorized as reflecting a *positive preference for the CAI modules* (participant liked using the CAI modules to learn) or *negative preference for the CAI modules* (participant disliked using the CAI modules to learn). Students who gave responses that were both positive and negative were counted as *ambivalent.* Students who clearly expressed indifference to the CAI modules as a learning experience were classified as *neutral.*

I read all of the journals again in an attempt to identify the most prevalent reasons the participants gave for their specified preferences. I specifically asked several questions designed to illicit responses to clarify why a participant did or did not like using the modules. For example, question five from the first journal asked participants to describe their initial reaction to the module Figure 4.1. While I provided a few leading questions immediately following the prompt, this question was open-ended for individual responses to vary. Other questions from the four journals asked the participant to give her or his preference for specific features of the CAI modules (see Figure 4.2). Appendices G-J contain all of the journal questions for each group and each module.

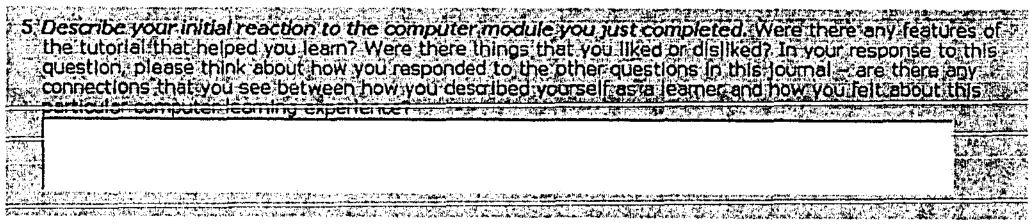

Figure 4.1 Open-Ended Question Sample, Journal 1

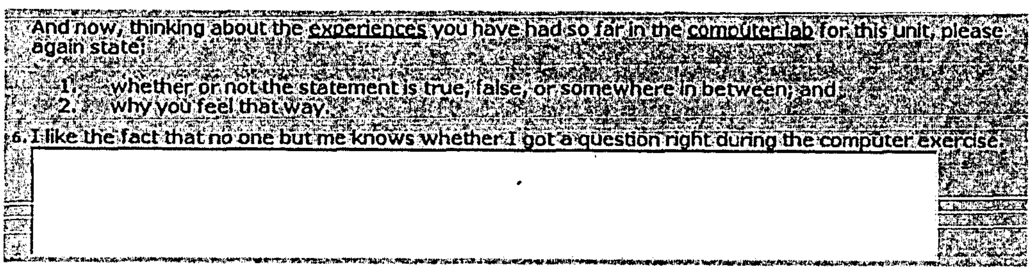

Figure 4.2 Specific Question Sample, Journal 3

Seven common responses in the *positive preference* journal entries were, (a) the information provided by the feedback was helpful for understanding why the answer was right or wrong (*information)*, (b) the encouraging nature of the audio feedback (groups D and E, only) made the participant feel better about her or his ability to answer questions correctly (*encouragement*), (c) other students did not know whether the participant had answered the questions incorrectly so there was no fear of embarrassment (*privacy*), (d) participants were able to identify which topics they needed to study more (*study)*, (e) the tutorials were self-paced so it was easy to take notes (*notes*), (f) in order to continue on to the next questions, participants must answer the current question correctly (*right*), and (g) using the computer was more interactive than being in the classroom (*interactive*). Each time one of these comments appeared in a journal, I counted the occurrence. The percentages for each reason are displayed in Table 4.2.

Table 4.2 Seven commonly provided reasons for why participants expressed a positive preference for using the CAI modules

Information	Encouragement	Privacy	Study	Notes	Right	Interactive
31.4%	9.2%	13.5%	12.4%	12.4%	9.2%	11.9%

Note. Each participant could be counted only once in each category, but may have been counted in more than one category, overall. These values represent the percentage of the total number of participants who gave one or more references to these reasons in the four journals compared to the total number of instances, per participant, of all seven reasons.

While reading the responses, I was somewhat surprised by how candid the students were when answering the questions about their individual learning experiences. Students also appeared very honest when asked about whether or not they guessed during the modules. Many admitted that they were simply too lazy to solve the problem, so they guessed instead. Because the model proposed by Bangert-Drowns, Kulik-Kulik, and Morgan (1991) cited the learner's willingness to mindfully process the feedback information as a key element in the ability of feedback to influence the learner's future initial states when answering questions in test-like events, I also categorized the journal responses into a *guessing* theme. Even though I was surprised by the candid nature of the participants journal entries, I was not surprised that the students chose to guess in the CAI modules. Presearch availability, a term coined by Kulhavy (1977), inhibits feedback from providing a significant role in promoting increased learner understanding. While the nature of the feedback provided (i.e., KOR, KCR, KCR+, TC/RC) varied by group and response accuracy in all of the CAI modules, the learners could access feedback immediately upon choosing any answer from the multiple choices available for each question. Because there was no motivation (e.g., points awarded or deducted) for the students to construct their own meaning prior to selecting an answer, it was extremely easy for the participants to put forth the least amount of effort possible to complete the task (Narciss, 2002). However, the TC/RC feedback provided in group E modules did not reveal the accuracy of the response choice at the start of the message. Learners had audio feedback for every choice. Incorrect choices received audio feedback designed to instruct the learner as to her or his mistake. I was curious as to whether or not this would discourage the participants from guessing because they could possibly finish the module faster by trying to solve every question without having to listen to as many as four incorrect audio feedback prompts before successfully guessing the correct answer (see Figures 2.1-2.8 for screen shots comparing the different feedback approaches). To investigate this possibility, I read all journal entries for each participant again. When students admitted to guessing when working through the four different CAI modules, their responses were categorized into the *learner guessed* subcategory. When students professed that they truly attempted to solve all problems, their responses were categorized into the *learner did not guess* subcategory.

After reading all responses from each participant, I categorized the learner into the two categories. I categorized the learner into the *learner guessed* category if he or she admitted to guessing at any time during the CAI modules. If the learner professed that he or she tried on all questions, I categorized the learner into the *learner did not guess* category. The group with the greatest percentage of guessers was group C, which fit with my expectations because the feedback in group C modules was limited to KOR and KCR text statements, making it very easy for students to guess on each question and quickly finish the modules. Group E participants admitted to guessing more often than group D participants (71% to 63%). I did not expect this result because I thought group E participants would be motivated by avoiding the long TC/RC feedback provided for incorrect answers and group D participants would find it easy to skip to the correct answer quickly because it was the only response that had audio feedback. The percentage for each group and overall are presented in Table 4.3.

Table 4.3 Percent of learners admitting to guessing by group

	Learner guessed	*Learner did not guess*
Group C	83%	17%
Group D	63%	37%
Group E	71%	29%
Total	72%	28%

Using a similar process as with the *preference* theme, I separated the *guessing* theme's categories into the common reasons that the students cited for their guessing behavior. In the *learner guessed* category, *laziness* was the most prevalent reason cited for why the student chose to guess on the questions instead of trying to work through the question on her or his own. In addition, learners also admitted to guessing when they *did not understand* what the question was asking, were *bored*, or they wanted to finish quickly. Finally, some students also admitted to guessing because they knew their performances on the module were *not graded.*

The responses from the *learner guessed* category for group C and D participants were very similar in the percents reported for each category. Both groups reported *laziness* roughly 40% of the time and *did not understand* for roughly 50% of the times reported guessing. The remainder 10% distributed amongst the other categories, *bored* and *not graded.* Group E participants also reported *laziness* approximately 40% of the time. However, the remaining 60% of guessing claims were attributed to *did not understand* (see Table 4.4).

Table 4.4 Categories for the *learner guessed* theme

	Laziness	*Did not understand*	*Bored*	*Not graded*
Group C	41%	50%	3%	6%
Group D	40%	48%	5%	7%
Group E	40%	60%	0%	0%

The *learner did not guess* category had fewer subcategories. Students who claimed to try their best when answering the questions cited a *desire to understand* the material and the *happiness* felt when an answer was correct as two reasons they did not guess during the module. Also, a few students stated that they were not afraid to try their best because even if they got the answer incorrect, no one would know it but them. All *learner did not guess* participants cited the categories approximately an equal number of times. I did not see any differences between the groups.

The last theme that emerged from reading the journal responses highlights the different ways students described how the feedback affected their confidence for answering future question like those given in the modules. I labeled this theme as the *effect of feedback on confidence.* Within this theme, most relevant responses could be classified as having positive, negative, or neutral effects. Interestingly, the overwhelming majority of comments made specifically about how feedback affects confidence were positive. Regardless of the students' preferences for the CAI modules or their guessing behavior, most students stated that the feedback did make them feel more confident about their ability to answer future questions correctly, both in the modules and on the unit examination.

Extraction of Significant Statements for Each Theme

I used NVIVO to organize the 500 plus pages of journal responses. Because the responses were all submitted electronically, I was able to import the documents directly into the computer program. After creating tree nodes for each theme, I generated the appropriate branches in the three main nodes (i.e., preference for CAI modules, guessing, and effect of feedback on confidence) for each of the theme's subcategories. Then, I used the software to link significant statements from the journal responses. The statements were considered significant if they directly related to the themes identified. These statements are not identified with any one particular participant. Instead, they represent my interpretation of all the comments made for each theme (i.e., *preference*, *guessing*, *confidence*). Because I already explored each theme for group similarities and differences, these statements are not group-specific. Instead, I use these statements and the meanings I developed from them to generate a textual descriptions of the different learners.

Table 4.5 Significant statements of positive comments

Positive statements
1. I really liked working on the computer because I knew when I had answered a question correctly immediately instead of having to wait for a test to be graded and returned.
2. It was good that I could not move to the next question until I got the right answer.
3. I like using the computer to review because it is easier for me to stay focused than when I am learning in the classroom.
4. I liked being able to take notes on the questions.
5. The questions in the module helped me figure out what I still needed to study before the test in class.
6. I like using the computer better than learning from a class lecture because it is more hands-on.
7. I liked that when I got an answer wrong, I was the only person who knew it.

Table 4.6 Significant statements of negative comments

Negative statements
1. I did not like working alone.
2. I did not like that there was not a total score given at the end of the assignment.
3. I did not like the modules because there was no teacher present to ask questions.
4. I did not like the modules because I still had to listen to the explanation even if I got the answer right (groups D and E only).
5. I thought the module was annoying.
6. I felt like the module was very condescending because of the way it explained all the answers (group E only).
7. I did not like the modules because it was too easy to just guess.

Table 4.7 Significant statements pertaining to guessing

Why learners guessed
1. I was too lazy to work out the calculation or get my calculator.
2. I did not try because I knew I was not being graded on my performance.
3. I did not try because I did not understand the questions.
4. I guessed because I was bored.

Table 4.8 Significant statements pertaining not guessing

Why learners did not guess
1. I tried hard on every question.
2. I wanted to see what I knew and what I did not know.
3. I wanted to get a good grade on the upcoming test so I paid attention and tried my hardest during the computer modules.
4. I did not guess because I knew that no one else would know if I got a question wrong, even after I tried hard to get it right.

Table 4.9 Significant statements pertaining to confidence, positive

Feedback positively affected confidence
1. The feedback made me feel good about myself.
2. I liked that the voice gave positive encouragement throughout the program (groups D and E only).
3. Because I knew whether I answered a question correctly, I was able to go back and figure out the ones I got wrong. This increased my confidence.
4. I feel like I learn better when I can correct my mistakes.
5. I get more motivated and do better when someone tells me "Good Job" or "Keep Trying." I do better because I know somewhere is supporting me and believes in me!
6. The computer makes me feel more confident because I know that if I got it right once then I can get it right again.

Table 4.10 Significant statements pertaining to confidence, negative

Feedback negatively affected confidence
1. I felt like the feedback was treating me like a little kid.
2. I thought the feedback was annoying and it decreased my desire to do well.

Table 4.11 Significant Statements of feedback not affecting confidence

Feedback did not affect confidence
1. The feedback did not affect my confidence because it is just a machine. I need a human to give criticism and encouragement for it to mean anything to me.
2. It does not make me feel more confident or less confident.
3. I do not really care what the computer tells me.
4. I know that everyone hears the same feedback, so it is not special to me.

Developing Meanings from the Significant Statements

After all of the data were coded and organized according to the various themes and subcategories, I reviewed all of the data again in order to generate a textural description of the different ways that the students experienced learning within the computer modules (Creswell, 1998). These descriptions include examples from the student journals. I edited these examples to correct spelling and grammar errors. I did not feel that any meaning was lost from performing these edits. Further, I believed the readability of the textural description was enhanced. A complete, unedited version of each verbatim example can be found in Appendix Q.

With the first textual description, I attempt to give a comprehensive representation of the types of responses given by students from any of the different feedback groups that liked the learning experiences offered by the CAI modules. The second textual description is an attempt to give a comprehensive representation of the types of responses given by the students who did not like learning in the CAI were no statistically significant differences observed in the quantitative ANCOVAs between the three different feedback groups on the ODA and SSE measures. I am operating under the theory that, because of the random assignment of participants to the three different treatment groups, that there may have been a "wash-out" effect of participants that liked and disliked the modules.

Textual Description of Learners who Liked the CAI Module Learning Experience

Participants who showed a preference for learning with the CAI modules cited changes to their somatic and emotional states and appreciation for the mastery experience opportunities as the primary reasons they liked using the modules. The students in groups D and E received audio feedback when they selected the correct answer, and students in group E also received audio feedback if they chose the incorrect answer describing the type of error they may have made that led them to select the incorrect choice. Also embedded in these feedback prompts were encouraging comments (e.g., you're really smart, I know you'll figure it out!). The following quotes illustrate these commonalities between three different students who expressed a preference for using the CAI modules. Their comments are representative of the types of responses given by other participants who liked learning with the CAI modules.

> I got to see what answers were wrong and feel good about the ones I got right away.
>
> The computer module showed me what I knew and helped me determine what answer was right and wrong. It showed me why I was wrong if I was wrong and explained why I was right. I think that is a very helpful tool to practice and study with if one has a test over certain material.
>
> I thought it did a good job and did help me learn what I had forgotten or didn't know. It also made me feel confident when I got the correct answer and, at the same time, it didn't bring me down if my answer was incorrect.
>
> I liked the way the computer had a kind response even when I guessed all answers but the right one. It encourages me to work better and pay attention when I'm complimented.
>
> The only person who knew I was wrong was me... in class many people don't participate because we are afraid to get the wrong answer.

Even though these students did not specifically relate their feelings to corresponding increases in self-efficacy, both changes to the somatic emotional state and mastery experiences have been consistently linked to increases in academic self-efficacy (Bandura, 1994; Bong & Skaalvik, 2003; Schunk & Pajares, 2001).

Textual Description of Learners Who Disliked the CAI Module Learning Experience

The students who disliked the CAI modules often expressed their disfavor because of the design of the questions and type of feedback they received. These students did not like the multiple-choice structure because it was very easy to guess to find the right answer. The following two students' responses provide a good example of the other comments from students in their category.

> I didn't like the fact that I couldn't go on until I got the right answer because, if my first answer wasn't right and my second answer wasn't right, then I just start clicking on things until it said I was right and let me move on.

> The only thing I didn't like was when you got an answer wrong it let you push the options until you got it right. This makes it easy for students to play around and not take it seriously because that gives you an option to guess and not to care. That's not really teaching anything, that's just giving answers away.

Students were randomly placed into treatment groups defined by the type of feedback the module delivered after students chose an incorrect or correct answer. The students in group C, who received only *correct* and *incorrect* feedback, often expressed a dislike for the modules because they felt that there was not any feedback given to help them learn why an answer was incorrect or correct. These examples are from two different students, both in group C. I chose these quotes because they were representative of the statements from the other participants in the same group and category.

> I don't really think that the computer gives me any feedback. It says, "correct, move on to the next question" or "incorrect, try again." If it explained to me why the answer was right or wrong, then that would be considered feedback.

> The feedback doesn't help me. Just because we spend a couple of days on a computer answering questions doesn't mean that now all the sudden I feel smarter and am able to go into my class and answer ever question and get the right answer. It actually makes me less confident then I was before because if I can't answer these questions without guessing until it says "correct" there is no way I will pass the test for this unit.

The students in group D received *incorrect* feedback when they selected an incorrect response. When they selected the correct response, audio feedback informed them of why that specific answer was correct. Group E participants received the same feedback as those in group D for correct responses. In addition, each of the incorrect choices had its own audio feedback that was designed to give the learner guidance as to what he or she may have done incorrectly that led to the incorrect choice. Also, the feedback gave hints to help the learner determine the correct answer with her or his next attempt. Many students in groups D and E expressed a dislike for the audio feedback, stating that it made them feel stupid, the feedback was too long, or the voice was annoying. The following six quotes are from six different students from group D or E who disliked the modules, specifically due to the feedback.

> It [the audio feedback] goes on and on and on... I don't think they should play the feedback if you get a problem right, because it kind of makes you feel stupid.
>
> I feel that the feedback is treating me like a five-year old, something I haven't been for almost thirteen years, and something I never want to be again. I feel like this program is insulting my intelligence!
>
> I thought it [the feedback] was corny and a little stupid, especially coming from a computer.
>
> Te computer feedback doesn't do anything for me. It doesn't help or make me feel better. It's not like I'm the only one who hears those words.
>
> The only way that I can feel confident about my ability to learn is if I can ask questions and do examples and maybe even get one-on-one help from the teacher sometimes. I don't like having to sit through a voice telling me why I

got the answer right or wrong. At least when I get the answer right on a test I don't have to hear why. If I got it right, I obviously knew the answer and why, so why discuss it.

...sometimes she talks too much and I don't want to hear her anymore. So then, I stop listening.

Triangulation Evidence from the Follow-up Interviews

I purposefully selected eight participants to participate in a semi-structured follow-up interview. These students were selected using both stratified purposeful and extreme or deviant case purposeful sampling strategies. Stratified purposeful sampling identified students from each group who, based on their journal entries, could facilitate comparisons between the subgroups. Additionally, students were identified as possible interview participants based on their journal entries that set them apart from the rest of the group because of their extreme like or dislike of the CAI modules. I did not factors (e.g., gender) in my selection process. Out of the eight students who consented to participate, six participated in a follow-up interview. The remaining students did not participate because they were absent on the day of the interviews. The interviews followed a semi-structured design and the participants were given a copy of the questions before we met for the session (see Appendix K).

Selected Statements from the Interviews

After I transcribed the interviews verbatim and subjected the transcriptions to the same analysis as the journal data, I found many similarities in the interviewees' responses that matched the themes and subcategories established from analyzing the journal responses for all participants. Thus, this analysis provided triangulation evidence to corroborate the meanings extracted from the larger journal sample.

Selected statements that corroborating the analysis of learners who liked the modules

The first interview participant, who I refer to as 'Airborne,' was selected from treatment group C because his journal responses indicated that he liked using the CAI modules and mindfully processed the KOR and KCR feedback to increase his understanding of the chemistry concepts presented in the modules. Similar to the textual description of learners who liked the CAI modules, 'Airborne' specifically cited the design of the module that forced students to get the correct answer before moving on to the next question as a reason why he thought the module was a good tool for his style of learning.

> I thought it was very effective only because...you usually have to go through the whole test and then come back. A lot of students are lazy so they're not going to come back and check every single answer. On that program, you were forced to get the right answer. You couldn't move on so that way you knew absolutely the right answer to the question before you could keep going. And that was very effective for me because it was the perfect way to centralize the answer because you had to learn it, otherwise you couldn't move on. Which was... a really good tool because most of the time people would skip over those kinds of things ...even though it might not have been the most important question, you still had to learn it because that had to happen for you to move on.

He also acknowledged that the module would only be effective if the learner was trying to gain understanding from the experience. He cited the immediate nature of the feedback as a primary reason for why he was able to gain from the module experiences.

> ...some people would argue that you know could cheat, because you know you get feedback or whatever. But, in my instance, and if there are people like me, trying to learn instead of just trying to breeze through things, like, that was very helpful for me, because after going through that whole unit, acids and bases and stuff like that, and questions I was wondering about, I was getting immediate answers, whereas if I would have had to come back to those, I might not have been able to.

> ... I had that red group so I wasn't getting any explanations or anything so I kinda just went for it. ...if you didn't get it right you just had to stay there... if you got the correct one then you could see all the wrong answers, see the right answer. And, just like I said, just like a tunnel vision to the right answer so you can basically correct your mistake immediately and I thought that was a really cool feature of that whole module.

When asked about the feeling he got when he was able to answer a question correctly on the first try, 'Airborne' clearly cited an increase in confidence and feelings of happiness as a result of his successes.

> Right on the first try? It was like; I'm on the money. There were a lot of instances in their where I got a big grip of them right and it fit. I mean it felt good... and you kinda get confidence every time you get a right answer.

The positive effects of the audio feedback encouragement messages were corroborated by another interviewee, who I will refer to as 'J.J.' I selected 'J.J.' from Group D because he indicated that he liked the encouragement the voice provided.

> I like the motivations that the lady in the module uses, "good job," "you're doing great," it just makes it easier to go on instead of getting yelled at for doing something wrong.

In his interview, he also identified praise from others as a significant source of self-efficacy.

> Maybe my parents saying, like, 'you're doing good' just keep goin' with that. Or, like, maybe even the teacher just saying that. Just positive stuff.

Both 'Airborne' and 'J.J.' stated that they enjoyed using the CAI modules and that they were more confident about their abilities to pass the examination at the end of the unit as a result of using the CAI modules.

> The computer makes me feel even though i had to try another time to get something right, when i do get that question right i know i will do better the next time.

> ...the feedback allowed me to see my errors or perfect what I already knew

Selected statements corroborating the analysis of learners who disliked the modules

The remaining interviewees were from groups C, D, and E. Two participants were selected from group C because they expressed different reasons for why they did not like the module as a learning experience. The participants from groups D and E were selected because they specifically highlighted the audio feedback as a reason for why they did not like the experience. Again, the reasons these participants gave for not liking the modules agreed with the findings from the analysis of the journal entries.

The interviewee named 'Snow' became very frustrated with the modules because, as a participant in group C, she did not receive detailed feedback.

> …I'd think, like, on every single question, like, you need to give a reason! And, um, that was really frustrating. I eventually went back and read the chapter over again and stopped guessing, but originally I just guessed and it actually frustrated me more than if I had somebody telling me what was the right answer.

Her frustration was mirrored by another group C participant,'Ali,' when I asked her about how the *correct* and *incorrect* feedback made her feel.

> Well because I wanted to learn… I mean, when I got "incorrect" it kindof frustrated me because I didn't know it and I *need* to know it.

Group D participants were represented by 'KB,' who felt strongly that the feedback was annoying and that it kept her from being able to learn.

> I almost felt like it [the feedback] was condescending because I knew the answer then it explained to me what I already knew…

This opinion was also shared by 'Jane,' from group E, and was even more strongly expressed because she had audio feedback for all choices.

> I hated listening to the feedback. I usually tuned it out until the "next question" icon appears. I especially hated listening to it when I missed the question because it takes forever!
>
> I just wanted to go on because I knew what it was, but it was still talking, like, I think that frustrated me a little bit because I was, like, I wanna go on to the next question, I wanna keep going, because I actually understand them. That goes back to that thing where if I can do it over and over again it helps me. So,

> I think that, because I thought I understood it, I was, like, OK I understand it, let me do another one… I think that just frustrated me a little.

Therefore, the follow-up interviews provided triangulation evidence that the textual summary highlighting the reasons why certain participants liked or disliked the CAI modules was an accurate representation of the phenomenon.

It is interesting to note that both interviewees selected who liked learning with the CAI modules were male. Whereas, all four interviewees that disliked learning with the CAI modules were female. When I chose each of eight potential participants from the raw journal data, I did not know the participant's gender. And, as it turned out, there seemed to be a clear gender line between those that liked and those that disliked learning with the CAI modules. However, gender is not a focus of this study. Therefore, I will leave it for future research to explore whether this division was coincidental or more indicative of a larger trend.

Discussion

The analysis and interpretation of the journal responses and interviews helped me contextualize how high school chemistry students in this study used CAI feedback. Three themes emerged during the analysis that addressed the two qualitative research questions, (a) How do students use different levels of feedback provided in computer assisted instruction modules? and (b) How do different types of feedback affect how confident a student is in her or his ability to learn science? These themes were labeled *preference for CAI*, *guessing*, and *confidence*.

The *preference for CAI* category, broken down by treatment group, showed that the groups were all very similar. Around two-thirds of all participants, regardless of group, clearly stated that they liked using the CAI modules as a learning tool. The remaining students were split almost evenly between the expressing a dislike for the CAI modules and remaining neutral about the tool as a learning experience. Therefore, I concluded that, in this study, the learner's overall preference for the CAI modules did not appear to depend on the type of feedback he or she received.

In contrast, the groups appeared different in terms of the percentage of learners that admitted guessing when answering the multiple-choice style questions in the CAI module. Participants in group C admitted guessing more than participants in groups D or E. I expected the group C participants to guess more often than the other participants because the CAI module did not contain any built-in immediate rewards or consequences to encourage mindful participation or discourage guessing (e.g., a grade for each module). Group D participants admitted to guessing the least of all groups. I was somewhat surprised by this finding because I expected the group D guess as often as group C participants because the group D modules were also designed with no built-in rewards or consequences. Further, I was surprised that the group E participants admitted to guessing the most. This was because I designed the group E modules to discourage guessing. In these modules, all answer choices were accompanied by extensive audio feedback. Thus, if a participant guessed on each question, he or she might have to listen to four or five feedback messages before selecting the correct answer. I thought that the consequence of having to spend a longer time listening to feedback would be an adequate motivator to encourage the participants to try their best to answer each question correctly in as few choices as possible.

The last theme, *confidence*, was reported very similarly in all groups. Nearly all participants stated that using the CAI modules positively affected their confidence for their performance on the unit examination (ODA posttest). Additionally, the participants attributed this gain to the feedback (even if it was limited to KOR and KCR) and the practice the modules provided.

After I compared the three groups across the different emergent themes, I continued to describe the learners' reasons (independent of group affiliation) provided in the journal responses that let me to label them according to the three themes and various categories. I decided to remove the group-by-group comparison emphasis because I became more interested in describing each type of learner. I thought this was a reasonable next step because I wanted to generate textural descriptions of the different ways that the students experienced learning within the computer modules. I hoped that these descriptions would help guide my recommendations for the design of CAI so that the full potential for CAI as a learning tool could be realized.

I ended up describing the two groups of learners most prevalent in the study, those who liked using the CAI modules as a learning experience and those who disliked using the CAI modules as a learning experience. These descriptions led me to two major conclusions about the participants, (a) high school students are very aware of the types of learning environments that match their individual needs and (b) it may be impossible to design CAI to match these needs unless the learner has some control over that design. The old adage "You can lead a horse to water, but you can't force him to drink" also comes to mind because using CAI, just like any learning environment, cannot force an unwilling student to learn.

Conclusion

About halfway though the qualitative data organization, I stopped and asked myself why on Earth I had decided to use a mixed-methods design for this dissertation study. The combination of both quantitative and qualitative methods was very difficult, and I was, quite frankly, tired. Now that the qualitative portion is completed, though, I feel like it was worth the effort it took to combine both approaches. The quantitative analysis corroborated my findings from the two pilot studies that failed to obtain enough evidence to suggest that the type of feedback in CAI could significantly affect participants' levels of science self-efficacy and academic achievement differently. However, the qualitative analysis revealed that, for the majority of participants, the CAI modules were both liked as a learning tool and able to affect the participants' confidence positively for future academic performances on similar concepts. Therefore, while I cannot conclude a causal relationship between feedback type and the dependent variables, I would still argue that the qualitative evidence supports the possibility that another study, with further design modifications, could potentially uncover a viable connection between these variables.

In chapter 5, I present provide a brief summary of the overall study. I discuss the overall limitations of my study and why I feel these reasons may have factored into the findings of both approaches. I also explore the possibility that the quantitative data, if grouped according to the theme that showed group differences, *guessing*, may have sufficient evidence to suggest that there is, in fact, a group difference on the SSE and ODA posttests if the guessing behavior is taken into account. Finally, my design recommendations for future studies and for CAI.

CHAPTER 5

SUMMARY OF THE RESEARCH FINDINGS AND INTERPRETATIONS

This chapter summarizes the results of this study and ties them back to the theoretical framework that guided the research questions and process. I also discuss features of the treatment conditions that may have occluded any potential significance and provide suggestions for future research. Next, I describe how I investigate the possibility that, if I only compared participants who claimed that they did not guess while answering the multiple-choice questions delivered in the CAI modules, there may actually be significant group differences on the posttests. Finally, I provide a set of broad design recommendations for CAI based on my experiences and the findings of my research endeavors.

Summary of the Research Design and Findings

This study used a mixed-methods approach in an attempt to illuminate the relationships between how feedback provided in computer-assisted instruction may be connected to the development of science self-efficacy. The quantitative data gathered assumed that changes to science self-efficacy would be evidenced by significant differences in posttest means on two measures. The first measure was developed by Britner and Pajares (2001) to measure science self-efficacy. The second measure was an objective-driven chemistry test that covered the concepts delivered over the course of the three-week chemistry unit on acids and bases. Both measures were given as a pretest and as a posttest. Students enrolled in first year chemistry at a suburban public high were randomly assigned to one of three treatment groups that varied by the type of feedback provided during four CAI modules that I designed using Macromedia Flash to match the chemistry objectives for the unit. Figures 2.1-2.8 contains a sample question from each module, recorded as screen shots of each question and the different feedback messages provided by group. I obtained written informed consent from both the student and her or his legal guardian prior to any analysis of the data. To ensure that all students, regardless of their status as a study participant, received instruction in the computer lab, all students were placed into the three different treatment groups and assigned a random 9-digit identification number. If a student did not provide written consent, I did not include their data in the analyses.

This study lasted three-weeks, during which students attended their regular chemistry class and received direct instruction from one of three different teachers. These teachers worked closely as a team and shared all materials such as quizzes, practice problems, and PowerPoint lecture outlines. In addition to the traditional curriculum for this unit, each teacher took her or his students to the computer lab four times to complete the CAI modules.

Treatment

Each module consisted of a series of multiple-choice questions, and these questions and answer choices were the same for each of the three treatment groups, labeled group C, group D, and group E. When the learner selected an answer to each question, he or she received feedback on the accuracy of her or his response.

The feedback provided for incorrect choices in group C consisted of a text message on the screen stating *incorrect, please try again.* Correct choices for module C received a text message stating *correct, advance to the next question.* The body of literature defining the different types of feedback has typically termed these types as knowledge of response (KOR) and knowledge of correct response (KCR) feedback.

The feedback provided for incorrect choices for group D modules was the same as group C for incorrect responses. However, when students chose the correct choice they received a detailed text message accompanied by a matching audio feedback of my voice reading the text that described why that choice was the best answer for that question. This type of feedback has typically been classified as a more elaborate form of KCR, and is labeled as KCR+ feedback.

Finally, the feedback provided for any choice in group E modules resulted in text and audio feedback which was specific for the particular answer chosen. I wrote the incorrect multiple-choice options very deliberately to include answer options that were plausible answers to the same question if that question was misinterpreted or common mistakes were made in calculations. Thus, the feedback for incorrect choices in group E was specific to the choice the learner made and provided specific text and audio feedback as to what error the student may have committed. The feedback also often contained hints as to how to solve the problem and answer correctly. This type of feedback is called *bug-related* because it assumes that the learner made a common error when answering the question and attempts to make the learner aware of her or his mistakes through instructive feedback to remediate the misconception. When the learner chose the correct answer in the group E modules, he or she received the same KCR+ text and audio feedback as the group D learners.

Qualitative and Quantitative Data

I also gathered qualitative data in the form of journal responses submitted electronically at the end of each of the four CAI modules. I designed the journal questions to both investigate the learners' levels of science self-efficacy and to learn more about how the learner interacted with the CAI module. These responses were submitted via email and linked to individual students by their randomly assigned 9-digit identification number. The journal responses were then organized and imported into NVIVO to perform the qualitative analysis. Before the end of the unit, I read all the journal responses and purposefully selected eight participants for a follow-up interview. Of the eight selected, six completed an interview. I generated verbatim transcripts of their responses and imported those documents into NVIVO.

I verified the random assignment by using SPSS to perform a one-way ANOVA on the pretest scores with group as the fixed factor. There were no significant differences between the groups on pretest scores for the ODA measure ($_{.95}F_{(2, 107)} = 1.003, p = .307$) or for the SSE measure ($_{.95}F_{(2, 107)} = .790, p = .457$). I also used the pretest scores as a covariate for the analysis of posttest scores for both measures as a way to increase the power of the tests.

The quantitative analysis consisted of two separate ANCOVAs on the dependent variables, using pretest as the covariate and group as the fixed factor. No significant differences were found for either measure between the three groups on adjusted posttest means for the ODA and SSE measures ($_{.95}F_{(2, 106)} = 1.311, p = 0.274$ and $_{.95}F_{(2, 106)} = 1.080, p = 0.344$, respectively). The lack of statistical significance was confounding because I had hypothesized that the students in groups D and E would show greater posttest scores on both measures because of the design of the feedback within the CAI modules. I then turned to the qualitative analysis to shed light on why no differences were observed.

Because the goal of the qualitative portion of this study was to understand more fully the phenomenon of how learners used feedback during the CAI modules and whether or not different types of feedback influence learners' level of academic achievement and science self-efficacy, I chose a phenomenological approach to generating the questions, analyzing the data, and reporting the findings. The origins of this discipline are in philosophy, sociology, and psychology because the intent is to "understand the essence of experiences about a phenomenon" (Creswell, 1998, p. 65). I analyzed the data collected in the form of journal responses and interviews to find significant statements and meanings in order to generate themes and general descriptions of the experiences of the learners in CAI modules. From this analysis, textual descriptions of the learners helped explain the quantitative findings and generated a broader understanding of how different learners used the feedback during the CAI modules.

The qualitative analysis revealed three main themes (a) preference for CAI, (b) guessing, and (c) effect of feedback on confidence. Significant statements for each theme were collected and organized according to logical similarities. For example, there were three types of learners in regards to their preferences for the CAI, those who (a) liked the modules, (b) disliked the modules, and (c) were neutral about liking or disliking the modules. I examined each of these themes thoroughly and generated a textual description of the two types of learners that may have affected the quantitative portion of the study. I hypothesized that the participants who liked using the CAI modules and those who disliked using the CAI modules would have the effect of cancelling each other out in the quantitative study. The grounds for this belief was because those who disliked the CAI module experiences also tended to guess on the multiple-choice questions and admittedly did not try very hard to learn during the experience. In contrast, the students who liked the modules interacted meaningfully with the modules and professed to have tried to learn from each question.

Connecting the Results to the Theoretical Framework

The three main concepts that I attempted to interrelate in this study are the development of ASE, feedback levels in CAI, and academic achievement. I believed that there was a logical connection between these facets via Albert Bandura's social-cognitive theory (1986) and the five-stage model of feedback processing proposed by Bangert-Drowns, Kulik, Kulik, and Morgan (1991).

Through his Social Cognitive Theory (1986), Albert Bandura details how individuals' self-efficacy (i.e., beliefs about their ability to complete tasks) can influence their control and management of learning. Of the various sources of self-efficacy (i.e., mastery experiences, vicarious experiences, verbal persuasion, and individuals' psychological and emotional states), I identified mastery experiences and verbal persuasion as two facets that feedback within CAI has the potential to influence. Because computer-assisted instruction has the ability to provide a potentially infinite number of questions, it also has the ability to promote the positive effects of mastery experiences. Bandura's model also specifically targets verbal persuasion as a source of self-efficacy beliefs. I was curious as to whether well-programmed CAI could deliver feedback capable using verbal persuasion to possibly affect the user's emotional state.

The Bangert-Drowns et al. (1991) model focuses on the mindful processing of feedback by the learner. They posited that learners not only respond to questions with a particular level of certitude, but also their mindful evaluation of the feedback provided to the response given can affect several of the learners' states, namely self-efficacy, interests, and goals. These changes to the learners' states can affect further learning experiences by altering the initial states of the learners in subsequent, similar environments.

A learner's level of self-efficacy for a given task can be directly affected by the evaluation of feedback provided to him or her in a learning environment and the learner's ability to evaluate her or his response depends on the feedback provided. It is reasonable, then, to expect that this feedback must also be of a quality that can encourage the reflective practices necessary for the learner's evaluation of her or his response to promote positive gains to the various states. When I considered these ways to affect self-efficacy (i.e., through the use of feedback in CAI designed to promote mastery experiences and use verbal persuasion to positively impact the learner's emotional state), I felt strongly that I would be able to design a series of CAI modules that I could use to test whether or not these types of feedback within CAI environments could actually result in significant differences between the groups, separated by type of feedback provided.

To measure any potential changes, I obtained permission to use the preexisting science self-efficacy measure developed by Britner and Pajares (2001). Finally, multiple connections between ASE and academic success have been widely researched throughout the last 2 decades (e.g., Pintrich & DeGroot, 1990; Schunk, 1991). Studies have shown that a student's beliefs about her or his ability to completed specific academic tasks directly affects her or his potential for realizing academic successes (Bong, 2002, 2004; Pajares & Miller, 1995; Pajares & Schunk, 2001a). Thus, I developed and used an objective-driven chemistry test, designed specifically to match the unit during which the treatment was given, to assess academic achievement.

I did not find any significant differences in adjusted posttest means for either measure using an ANCOVA on a total of 109 participants. There are many possible explanations for why there appeared to be no differential effect from the treatments. First, the study only lasted for three-weeks and only included four instances of the treatment. A more longitudinal study may have the ability to uncover significance because the brief nature of this study may have enhanced treatment effects due to the novelty of going to the computer lab to review, regardless of which type of module the participants used. Also, I found out after the conclusion of the study that many students were not utilizing the audio feedback provided. Instead, they used the computer program *iTunes* to listen to music, drowning out the verbal feedback. While the text for the verbal feedback was also displayed on the screen, many students admitted in their journal entries that they did not pay attention to the feedback provided. Thus, any potential treatment effects from the audio delivery of the KCR+ and bug-related feedback would be nullified.

Finally, the qualitative analysis helped me shed light on the way that various students interacted with the computer tutorials and used the feedback to help them learn the chemistry objectives and content reviewed in the modules. There were clearly defined groups of students who expressed a strong like and a strong dislike for the modules. Further, the journal responses from students who liked the modules indicated that they also tried to participate actively in the learning process by not guessing and by reviewing and taking notes during the modules. Students who expressed a strong dislike for the modules also admitted to guessing on the questions and not making a concerted effort to gain understanding of the concepts from the modules. It is possible, therefore, that these two extreme types of learners negated each other in the quantitative analysis.

Limitations and Design Flaws

There are many possible explanations for why there appeared to be no differential effect from the treatments. First, the study only lasted for three-weeks and only included four instances of the treatment. A more longitudinal study may have the ability to uncover significance because the brief nature of this study may have enhanced treatment effects due to the novelty of going to the computer lab to review, regardless of which type of module the participants used. Also, I found out after the conclusion of the study that many students were not utilizing the audio feedback provided. Instead, they used the computer program *iTunes* to listen to music, drowning out the verbal feedback. While the text for the verbal feedback was also displayed on the screen, many students admitted in their journal entries that they did not pay attention to the feedback provided. Thus, any potential treatment effects from the audio delivery of the KCR+, TC, and RC feedback would be nullified.

Finally, the qualitative analysis helped me shed light on the way that various students interacted with the computer tutorials and used the feedback to help them learn the chemistry objectives and content reviewed in the modules. There were clearly defined groups of students who expressed a strong like and a strong dislike for the modules. Further, the journal responses from students who liked the modules indicated that they also tried to participate actively in the learning process by not guessing and by reviewing and taking notes during the modules. Students who expressed a strong dislike for the modules also admitted to guessing on the questions and not making a concerted effort to gain understanding of the concepts from the modules. It is possible, therefore, that these two extreme types of learners negated each other in the quantitative analysis.

Analyzing the Non-Guessing Learners

I was extremely curious about whether the data would reveal any significant differences for the posttest adjusted means of only those participants who reported in their journals that they did not guess during the CAI modules. To investigate this possibility, I classified the participants in my SPSS data file according to the category they were assigned for the *guessing* theme in the qualitative analysis (Group C, $N = 6$; Group D, $N = 9$; Group E, $N = 8$). Next, I performed two new ANCOVAs on the dependent variables. Even with the participants who admitted to guessing removed, no significant differences between any pairwise combination of the three treatment groups on adjusted posttest means were observed. However, the new ANCOVA on the SSE measure resulted in enough evidence ($\alpha = .10$) to suggest that there was at least one pairwise group difference between the adjusted SSE posttest means $({}_{.90}F_{(2, 19)} = 3.222, p = 0.062)$. The unadjusted and adjusted posttest means for the SSE measure are presented in Table 5.1 and Table 5.2, respectively. The summary of the ANCOVA analysis is presented in Table 5.3. The post hoc multiple-comparisons procedure showed significant pairwise differences between both groups C and D and groups E and D, with the adjusted posttest means of group D higher than the other two groups. The small sample size ($N = 23$), however, tempered my enthusiasm for these results and further research would be necessary for me to state conclusively that the SSE of group D participants was more positively affected by the feedback than the SSE of groups C and E participants.

Table 5.1 Summary of non-guessers' unadjusted posttest means for the SSE

GROUP	Mean	Std. Deviation	*N*
Group C	204.33	44.446	6
Group D	215.39	15.520	9
Group E	203.88	34.725	8
Total	208.50	30.857	23

Table 5.2 Summary of non-guessers' adjusted posttest means for the SSE measure

			95% Confidence Interval	
GROUP	Mean	Std. Error	Lower Bound	Upper Bound
Group C	201.056[a]	6.468	187.518	214.595
Group D	218.987[a]	5.290	207.915	230.060
Group E	202.285[a]	5.594	190.577	213.993

[a]Covariates appearing in the model are evaluated at the following values: PRETEST = 209.50.

Table 5.3 ANCOVA summary table for the SSE measure

Source	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.
Adjusted Between	1610.992	2	805.496	3.222	.062
Adjusted Within	4749.914	19	249.995		
Covariate	15495.183	1	15495.183	61.982	.000
Corrected Total	20947.500	22			

Design Recommendations for CAI

Now, at the conclusion of my research endeavors, one thing I can state with certainty is that it takes a tremendous amount of effort, time, and knowledge to construct computer modules that contain detailed feedback for users. The design and development of the modules I used for this study (not to mention the other, different modules used in the two pilot studies) took hundreds of hours that included choosing appropriate and well-written multiple-choice questions that aligned to the unit objectives, storyboarding each question and each response feedback message, and finally, programming an interactive CAI experience using Macromedia Flash™. I am no longer surprised that the CAI typically available from textbook publishers is limited to the less complicated feedback forms of KOR and KCR.

However, over the course of the last four years since my journey down the path of this dissertation began, I have been acutely aware of the growing number of Web-based courses offered within my district. We currently offer two online science courses that are delivered entirely over the Internet and no face-to-face instruction is provided for the learners. Students even complete their science laboratory experiments outside of the school building using common household items and chemicals. Other laboratory experiments are completed "virtually" using software available via CD or Web-based programs delivered via the Internet. Now, granted, these classes are still moderated by a licensed science teacher. However, he or she no longer has the face-to-face connection that I would argue is essential for "hooking" science students well enough to encourage a future career in the sciences.

Regardless of whether CAI is used in the classroom with a face-to-face teacher or in a distance education program with an online teacher, it is in our best interest as science educators to continually strive towards making the process of learning and understanding science exciting and rewarding. Computer-assisted instruction has the potential to offer a customizable interface that is tailored to match an individual learner's needs. My major suggestion for CAI design, therefore, is to provide users with options for what type(s) of feedback are available for them during the CAI experience. This could be accomplished by having students complete an initial survey designed to explore their personal preferences for the feedback delivery and content. This survey could also include items to gauge the user's personality and then try to match each individual user to the type of feedback personality (e.g., supportive, friendly, impersonal, or technical) best suited to their needs. Another possibility for including user choice in the design of how the feedback is presented would be to allow users to choose the type of feedback they would like on a question-by-question basis. Still, both these options continue to work under the basic premise that the learner must desire to gain knowledge and understanding. Therefore, it is possible that including these features would not actually affect the learner's performance on future examinations or the learner's overall confidence for demonstrating mastery of the content. Based on the assumption that more effort, time, and knowledge would be required to successfully design the program, it is reasonable to conclude that these programs would cost more money to produce. Software designers, then, must weigh the increased cost of development against the possibility that the newer programs will be no better than their previous versions at promoting academic success.

Of the three feedback designs that I presented in this study, I would recommend the KOR/KCR+ approach used in the group D modules over the KOR/KCR and KOR/KCR+/TC/RC feedback offered in groups C and E, respectively. It is interesting to note that, while not statistically significant ($\alpha = .05$), in both the ODA and SSE ANCOVAs, group D had the highest adjusted mean. Also, the percent of group D participants who reported guessing during the modules was the lowest of all three groups. Finally, it required much less time to program the KCR+ feedback than the more elaborate TC/RC feedback for the group E modules.

Suggestions for Future Research

I was unable to confirm statistically any of my original hypotheses about how feedback could affect self-efficacy, and consequently academic achievement. It would be prudent for future research to include a power analysis prior to initiating a study. I did not perform a power analysis and my results would be understood more fully as an initial point for further research if a power analysis were performed. Even though I am disappointed that my theories were not supported by the quantitative analysis of this study, I am not convinced that flaws in the theoretical foundation for my hypotheses were to blame. Other researchers have also had troubles identifying the relationship between feedback and achievement, as evidenced by the lack of consensus between studies as to what type of feedback promotes learning the best. Numerous studies have investigated the relative effects of the more simple feedback types (i.e., KOR, AUC, KCR, and KCR+) on academic achievement (e.g., Clariana, 2001; Clark & Dwyer, 1998; Gordijn & Nijhof, 2002). However, while the designs of these studies are often similar, the researchers' results fail to combine to create a body of evidence either in support or against a hypothesis that states that increasing feedback complexity also increases academic achievement (see reviews in Azevedo & Bernard, 1995; Bangert-Drowns et al., 1991; Clariana, 1993; Mory, 1996, 2004).

Perhaps future research should isolate students that use the feedback provided mindfully, regardless of the complexity of the feedback. I would argue that the mixed-methods approach would still be necessary to ensure that these students could be identified and that the researcher could be more aware of the learner's thoughts during the feedback processing stages proposed by Bangert-Drowns, Kulik, Kulik, and Morgan (1991). I believe, that only through this approach and modifications may evidence to support the ties between feedback in CAI, self-efficacy, and academic achievement that logically exist based on the connecting social cognitivist theories.

I also argue that this is still a valuable area of research. While this study focused on feedback given in CAI, more and more instruction is being facilitated by using computers. Examples of these types of learning environment range from simple review programs, similar to the CAI modules in this study, to full degree programs delivered online via an accredited university and professors teaching using asynchronous and synchronous learning environments with no face-to-face interaction. The myriad possibilities of the effects of feedback in any of the computer-mediated or computer-delivered educational experiences could help computer software designers, online instruction program designers, and other educators to develop more effective computer-assisted learning experiences.

APPENDIX A
PARENT/GUARDIAN CONSENT FORM

Dear Parent/Guardian,

My name is Diann Mazingo and I have your student in honors chemistry this year at Eaglecrest High School. In addition to teaching at Eaglecrest, I am also pursuing a PhD at the University of Colorado at Denver. As part of my dissertation research, I am performing a series of research studies at Eaglecrest involving students in my honors chemistry classes. This letter describes the purpose, activities, risks, and benefits associated with the study I am completing as a part of a research class this fall. It is also a pilot of the research I hope to perform for my dissertation. If, after reading this letter, you are willing to give your consent for your student to participate, please sign and date the back of this form and return it with your student to school. Thank you for your time and support of my continuing education.

Purpose of Research:

Your student is being asked to participate in a research study to explore the effects of feedback in computer-assisted instruction (CAI) modules. In particular, I am interested in whether or not a computer's responses to student answers to practice chemistry problems has any effect of how capable they feel about their ability to answer questions correctly.

Activities:

This study will take place during the normal class time for your student's regularly scheduled chemistry class. There will be an initial survey of her or his science self-efficacy, or their personal beliefs about their capabilities as a science student. The same survey will be given again at the end of the study. Additionally, there will be a pretest of her or his knowledge of the following chemistry topics: states of matter, phase changes, and thermochemistry. The pretest score will not influence their grade in any manner, but will only be used to determine how much is learned throughout the study. The chemistry posttest is the normal test that is given at the end of this unit; and will, like usual, count in for a grade. In between the pretest and posttest, students will participate in all the normally scheduled class activities, including several trips to the computer lab.

If you choose to give your consent for your student to participate, there will be a small chance that s/he will be asked to participate in a follow-up conversation with me when I will ask them questions about how well they learned from the CAI modules, and other questions related to their beliefs about how well they learn science. Only a few students will be asked to have this additional meeting.

Duration:

Unless selected for a follow-up conversation, all activities that are part of this study will take place during the regularly scheduled class time, or as the standard (not extra) homework for the class. If your student is selected for the follow-up conversation, it will occur during a study period or other available time within the normal school day.

Risks and Confidentiality:

There are a couple of things I want to make sure you know that *could* happen to your student during this study. While there are no known physical risks, there may be times when he or she feels embarrassed or frustrated as a result of not understanding the chemistry concepts or how to work the computer module. I will try very hard to ensure a safe learning environment. There's also a small possibility that confidentiality will be breached. If other students find out a student's randomly assigned identification number, they may have access to the student's grade if they can access the password-protected file on my laptop.

Multiple efforts to maintain confidentiality will be taken, such as: random assignment of an identification number that only I have access to, and secure storage of all documents and assessments. Additionally, your student's name will never be used in any written documentation.

Benefits:

Benefits to participation include the potential for knowledge and self-efficacy gains during the CAI module interactions. If chosen to participate in the follow-up conversation with the researcher, students may benefit from additional time with the researcher reflecting on their participation in the study as it relates to their own learning styles.

Voluntary Participation:

Participation in the study is voluntary and requires informed consent signatures from both the student and her or his legal guardian. You are free to withdraw your student from this study at any time for any reason. Since the study is being conducted as part of her or his regular class, the only difference between students who choose to participate and those who do not will be what data is recorded as part of the study. If you choose not to provide consent for your student to participate, s/he will still be expected to complete the class activities as part of their normal chemistry curriculum; however, no data from their participation would be used in the study. There will be no penalties or loss of benefits from withdrawing or declining participation.

Further Information:

If you have additional questions about the research project, before, during, or after participation, please contact me, Diann Mazingo, at 720-886-1102, or via email at dmazingo@cherrycreekschools.org. You may also contact the HRSC Administrator at CU Denver (Suite 740, 303-556-4060) with any questions concerning your rights as the guardian of a research participant. Written permission from the Eaglecrest High School administration has also been obtained, and school officials are aware that this study will be taking place.

If you are willing to consent for your student to participate in this study, please sign a copy of this consent form and return it to me. There is another, similar form for the student to read and sign.

Sincerely,

Diann Mazingo

Please sign below. You will be provided with a copy of this consent form to keep.

I consent to allow my student to participate in this study. I understand that all information gathered in this study will be kept confidential, that student participation is voluntary, and that I may withdraw my student from the study at any time for any reason.

Guardian Name (please print): ____

Guardian Signature: ____ Date: ____________

APPENDIX B
STUDENT CONSENT FORM

Voluntary Participation:

Your participation in this study is voluntary. You are free to withdraw from this study at any time for any reason. Since the study is being conducted as part of your regular class, the only difference between students who choose to participate and those who do not will be what data is recorded as part of the study. If you choose not to participate, you will still be expected to complete the class activities as part of your normal chemistry curriculum; however, no data from your participation would be used in the study. There will be no penalties or loss of benefits from withdrawing or declining participation.

Further Information:

If you have additional questions about the research project, before, during, or after participation, please contact me, Diann Mazingo, at 720-886-1102, or via email at dmazingo@cherrycreekschools.org. You may also contact the HRSC Administrator at CU Denver (Suite 740, 303-556-4060) with any questions concerning your rights as a research participant. Written permission from the Eaglecrest High School administration has also been obtained, and school officials are aware that this study will be taking place.

If you are willing to participate in this study, please sign a copy of this consent form and return it to me. There is another form for your legal guardian to read and sign.

Sincerely,

Diann Mazingo

Please sign below. You will be provided with a copy of this consent form to keep.

I agree to participate in this study. I understand that all information gathered in this study will be kept confidential, that my participation is voluntary, and that I may withdraw from the study at any time for any reason.

Student Name (please print): ______________________________

Student Signature: ______________________________ Date: __________

APPENDIX C
BUILDING CONSENT FOR STUDY SITE

Eaglecrest High School
5100 South Picadilly Street
Centennial, Colorado 80015
720-886-1000

Cherry Creek Schools
Dedicated to Excellence

3 October 2003

To Whom It May Concern:

This authorizes Diann Mazingo, a teacher at Eaglecrest High School in Centennial, Colorado, to have permission to collect data from students as a part of her research in the Educational Leadership and Innovation PhD program at the University of Colorado at Denver (UCD). This permission is contingent on the fact that Diann receives written permission from both the student and the student's legal guardian. I understand that Diann will take the necessary precautions to maintain student confidentiality and that all data will be reported and stored according to regulations set forth by the UCD Human Subjects Review Committee.

Authorized Signature

Diann Mazingo
Teacher, Eaglecrest High School

Authorized Signature

Jeanne Piper
Principal, Eaglecrest High School

APPENDIX D
HUMAN SUBJECTS REVIEW COMMITTEE APPROVAL DOCUMENTATION

University of Colorado at Denver

HUMAN SUBJECT RESEARCH COMMITTEE
University of Colorado at Denver
Campus Box 129, P.O. Box 173364
Denver, CO 80217-3364

MEMORANDUM

DATE: October 23, 2003

TO: Diann Mazingo

FROM: Deborah Kellogg, HSRC Chair

SUBJECT: Human Subjects Research Protocol #2004-034 – Investigating the effects of feedback on academic self-efficacy and academic achievement in computer-assisted chemistry instruction

Your protocol, with changes, has been approved as non-exempt and should pose no more than minimal risk. This approval is good for up to one year from this date.

Your responsibilities as a researcher include:

- If you make changes to your research protocol or design you should contact the HSRC.
- You are responsible for maintaining all documentation of consent. Unless specified differently in your protocol, all data and consents should be maintained for three years.
- If you should encounter adverse human subjects issues, please contact us immediately.
- If your research continues beyond one year from the above date, contact the HSRC for an extension.

The HSRC may audit your documents at any time.

Good Luck with your research.

APPENDIX E
OBJECTIVE-DRIVEN ASSESSMENT

1. Acids taste
   a. sweet.
   b. sour.
   c. bitter.
   d. salty.
2. Acetic acid is found in significant quantities in
   a. lemons.
   b. vinegar.
   c. sour milk.
   d. apples.
3. Acids react with
   a. bases to produce salts and water.
   ~~b. salts to produce bases and water.~~
   c. water to produce bases and salts.
   d. neither bases, salts, or water.
4. A substance that ionizes nearly completely in aqueous solutions and produces H_3O^{1+} is a
   a. weak base.
   b. strong base.
   c. weak acid.
   d. strong acid.
5. Which of the following is NOT a strong acid?
   a. HNO_3
   b. CH_3COOH
   c. H_2SO_4
   d. HCl
6. ~~Which of the following is a strong acid?~~
   a. HSO_4^{1-}
   b. H_2SO_4
   c. CH_3COOH
   d. H_3PO_4
7. Hydroxides of Group 1 metals
   a. are all strong bases.
   b. are all weak bases.
   c. are all acids.
   d. might be strong or weak bases.
8. Which of the following is a strong base?
   a. NH_3
   b. Aniline
   c. NaOH
   d. Acetate ion
9. Strong acids are
   a. strong electrolytes.
   b. weak electrolytes.
   c. nonelectrolytes.
   ~~d. weak acids.~~
10. Strong bases are
    a. strong electrolytes.
    b. weak electrolytes.
    ~~c. nonelectrolytes.~~
    d. also strong acids.
11. Many organic compounds, such as aniline, that contain nitrogen are
    a. strong bases.
    b. weak bases.
    c. strong acids.
    d. weak acids.
12. What is the equation for the ionization of water?
    a. $2H_2O(l) = H_3O^{1+}(aq) + OH^{1-}(aq)$
    b. $2H_2O(l) = H_3O^{1-}(aq) + OH^{1+}(aq)$
    c. $2H_2O(l) = 2H_2(g) + O_2(g)$
    d. $H_2O(l) = H^{+}(aq) + OH^{+}(aq)$
13. To what degree does water ionize?
    a. Completely
    ~~b. To a large extent~~
    c. Slightly
    d. Not at all
14. What is the value of the equilibrium constant for water?
    a. 0
    b. 10^{-14}
    c. 10^{-7}
    d. 55.4
15. What is the symbol for the equilibrium constant for water?
    a. K_w
    b. K_a
    c. K
    d. K_{sp}
16. The pH of a solution is 9. What is its H_3O^{1+} concentration?
    a. 10^{-9} *M*
    b. 10^{-7} *M*
    c. 10^{-5} *M*
    d. 9 *M*
17. The pH of a solution is 10. What is its OH^{1-} concentration?
    a. 10^{-10} *M*
    b. 10^{-7} *M*
    c. 10^{-4} *M*
    d. 10 *M*
18. Pure water contains
    a. water molecules only.
    b. hydronium ions only.
    c. hydroxide ions only.
    ~~d. water molecules, hydronium ions, and hydroxide ions.~~
19. What is the concentration of H_3O^{1+} ions in pure water?
    a. 10^{-7} *M*
    b. 0.7 *M*
    c. 55.4 *M*
    d. 10^{7} *M*

20. A Bronsted-Lowry acid is
a. an electron-pair acceptor.
b. an electron-pair donor.
c. a proton acceptor.
d. a proton donor.

21. In the equation $HCl(g) + H_2O(l) \rightarrow H_3O^{1+}(aq) + Cl^{1-}(aq)$, which species is a Bronsted-Lowry acid?
a. HCl
b. H_2O
c. Cl^{1-}
d. None of the above.

22. The reaction $HCl + KOH \rightarrow KCl + H_2O$ is a
a. single-replacement reaction.
b. synthesis reaction.
c. Bronsted-Lowry acid-base reaction.
d. Lewis acid-base reaction.

23. Which of the following is a diprotic acid?
a. H_2SO_4
b. HCl
c. CH_3COOH
d. H_3PO_4

24. Which of the following is a triprotic acid?
a. H_2SO_4
b. HCl
c. CH_3COOH
d. H_3PO_4

25. How many H^{1+} ions will a monoprotic acid release upon dissociation?
a. Zero
b. One
c. Two
d. Three

26. A conjugate base is the species that
a. remains after a base has given up a proton.
b. is formed by the addition of a proton to a base.
c. is formed by the addition of a proton to an acid.
d. remains after an acid has given up a proton.

27. A conjugate acids is the species that
a. remains after a base has given up a proton.
b. is formed by the addition of a proton to a base.
c. is formed by the addition of a proton to an acid.
d. remains after an acid has given up a proton.

28. The members of a conjugate acid-base pair
a. appear on the same side of the chemical equation.
b. appear on opposite sides of the chemical equation.
c. might appear on the same side or opposite sides of the chemical equation.
d. are not included in the chemical equation.

29. What is the acid-ionization constant, K_a, for the ionization of acetic acid, shown in the reaction $CH_3COOH(aq) + H_2O(l) \rightleftharpoons H_3O^{1+}(aq) + CH_3COO^{1-}(aq)$?
a. $[H_3O^{1+}][CH_3COOH^{1-}]$
b. $\dfrac{[H_3O^{1+}][CH_3COO^{1-}]}{[CH_3COOH][H_2O]}$
c. $\dfrac{[H_3O^{1+}][CH_3COO^{1-}]}{[CH_3COOH]}$
d. $\dfrac{[CH_3COOH]}{[CH_3COO^{1-}][H_3O^{1+}]}$

30. How do K_a values for weak and strong acids compare?
a. K_a (weak) = K_a (strong)
b. K_a (weak) < K_a (strong)
c. K_a (weak) > K_a (strong)
d. K_a is not defined for weak acids.

31. Which expression represents the pH of a solution?
a. $\log[H_3O^{1+}]$
b. $-\log[H_3O^{1+}]$
c. $\log[OH^{1-}]$
d. $-\log[OH^{1-}]$

32. What is the pH of a neutral solution at 25°C?
a. 0
b. 1
c. 7
d. 14

33. The pH scale, in general, uses ranges from
a. 0 to 1.
b. -1 to +1.
c. 0 to 7.
d. 0 to 14.

34. The pH of an acidic solution is
a. less than 0.
b. less than 7.
c. greater than 7.
d. greater than 14.

35. The pH of a basic solution is
a. less than 0.
b. less than 7.
c. greater than 7.
d. greater than 14.

36. A water solution whose pH is 4
a. is always neutral.
b. is always basic.
c. is always acidic.
d. might be neutral, acidic, or basic.

37. A water solution whose pH is 10
a. is always neutral.
b. is always basic.
c. is always acidic.
d. might be neutral, acidic, or basic.
38. A water solution whose pH is 7
a. is always neutral.
b. is always basic.
c. is always acidic.
d. might be neutral, acidic, or basic.
39. To calculate the pH of a solution whose $[OH^{1-}]$ is known, first calculate
a. $[H_3O^{1+}]$
b. $\log[OH^{1-}]$
c. $\text{antilog}[H_3O^{1+}]$
d. $[H_3O^{1+}]$
40. What is the pH of a 10^{-4} *M* HCl solution?
a. 4
b. 6
c. 8
d. 10
41. What is the pH of a 10^{-5} *M* KOH solution?
a. 3
b. 5
c. 9
d. 11
42. If $[H_3O^{1+}] = 1.7 \times 10^{-3}$ *M*, what is the pH of the solution?
a. 1.81
b. 2.13
c. 2.42
d. 2.77
43. What is the pH of a solution whose hydronium ion concentration is 5.03×10^{-1} *M*?
a. 0.2984
b. 0.5133
c. 1.542
d. 5.031
44. What is the pH of a 0.027 *M* KOH solution?
a. 6.47
b. 12.43
c. 12.92
d. 14.11
45. What is the hydronium ion concentration of a solution whose pH is 7.30?
a. 1.4×10^{-11} *M*
b. 3.8×10^{-8} *M*
c. 5.0×10^{-8} *M*
d. 7.1×10^{-6} *M*
46. Dyes with pH-sensitive colors are used as which of the following?
a. Primary standards
b. Indicators
c. Titrants.
d. None of the above.
47. The pH range over which an indicator changes color is its
a. equivalence point.
b. endpoint.
c. transition interval.
d. pH interval.
48. The substances produced when KOH(aq) neutralizes HCl(aq) are
a. HClO(aq) and KH(aq).
b. KH_2O^{1+}(aq) and Cl^{1-}(aq).
c. H_2O(l) and KCl(aq).
d. H_3O^{1+}(aq) and KCl(aq).
49. What is neutralization?
a. An acid-base reaction that does not include dissociation of ions.
b. A reaction of hydronium ions and hydroxide ions to form a salt.
c. A reaction of hydronium ions and hydroxide ions to form water molecules.
d. A reaction of hydronium ions and hydroxide ions to form water molecules and a salt.
50. What process measures the amount of a solution of known concentration to react with a measured amount of a solution of unknown concentration?
a. Autoprotolysis
b. Hydrolysis
c. Neutralization
d. Titration
51. An acid-base titration involves a
a. composition reaction.
b. neutralization reaction.
c. single-replacement reaction.
d. decomposition reaction.
52. In an acid-base titration, equivalent quantities of hydronium ions and hydroxide ions are present
a. at the beginning point.
b. at the midpoint.
c. at the end point.
d. throughout the titration.
53. During an acid-base titration, a very rapid change in pH
a. occurs when the first addition of the known solution is made.
b. occurs when the amounts of H_3O^{1+} and OH^{1-} are nearly equivalent.
c. occurs at several points during the titration.
d. does not occur during titration.

54. The point in a titration when the amount of OH^{1-} ions exactly equals the amount of H^{1+} ions is called the

a. equivalence point.
b. buffer point.
c. end point.
d. transition point.

55. An acid-base titration is carried out by monitoring

a. temperature.
b. pH.
c. pressure.
d. density.

56. What is the molarity of an NaOH solution if 4.37 mL is titrated by 11.1 mL of 0.0904 *M* HNO_3?

a. 0.230 *M*
b. 0.355 *M*
c. 0.460 *M*
d. 0.620 *M*

57. What is the molarity of an H_2SO_4 solution if 49.0 mL is completely titrated by 68.4 mL of an NaOH solution whose concentration is 0.333 *M*.

a. 0.116 *M*
b. 0.232 *M*
c. 0.465 *M*
d. 0.880 *M*

58. What is the molarity of a $Ba(OH)_2$ solution if 1900 mL is completely titrated by 261 mL of 0.505 *M* HNO_3?

a. 0.0173 *M*
b. 0.0254 *M*
c. 0.0322 *M*
d. 0.0347 *M*

59. If 72.1 mL of 0.543 *M* H_2SO_4 completely titrates with 39.0 mL of KOH solution, what is the molarity of the KOH solution?

a. 0.317 *M*
b. 0.502 *M*
c. 1.00 *M*
d. 2.01 *M*

60. What is the molarity of a $Ba(OH)_2$ solution if 93.9 mL is titrated by 15.3 mL of 0.247 *M* H_2SO_4?

a. 0.0101 *M*
b. 0.0201 *M*
c. 0.0402 *M*
d. 0.0805 *M*

APPENDIX F
SCIENCE SELF-EFFICACY MEASURE

PLACE ONE IDENTIFICATION STICKER IN THE BOX.

Do not write your name on this form.

Thank you for taking the time to help me out with my dissertation research!

The following set of questions were designed by a couple of professors at Emory university and have been used in many studies to help develop an understanding of how students perceive their ability to learn science. Since you will only be identifying yourself on this form with a randomly assigned identification number, you can feel safe that your responses will remain confidential and will only be used for the purposes of this study.

Therefore, please take the time to read each question carefully. It is important that you do not leave any questions blank. Mark your answer by circling the most appropriate number or letter that you think best describes you.

Again, please answer each question. Thank you for your participation and help!

-Diann Mazingo

Science Self-Efficacy Measure

Using the scale from 1 (*not confident at all*) to 6 (*completely confident*), please answer the following questions as honestly as you can, as you believe they apply to yourself by ***circling*** the number. *There are no right or wrong answers to these statements.*

1	2	3	4	5	6
Not confident at all					Completely confident

01	*How confident are you* that you will **pass science class *at the end of the semester*?**	1	2	3	4	5	6
02	*How confident are you* that you will pass science at the end of this semester **with a grade better than a "D"** (60% or higher)?	1	2	3	4	5	6
03	*How confident are you* that you will pass science at the end of this semester **with a grade better than a "C"** (70% or higher)?	1	2	3	4	5	6
04	*How confident are you* that you will pass science at the end of this semester **with a grade better than a "B"** (80% or higher)?	1	2	3	4	5	6
05	*How confident are you* that you will pass science at the end of this semester **with an "A"** (90% or higher)?	1	2	3	4	5	6

Using the scale from 1 (*not very well at all*) to 6 (*very well*), please answer the following questions as honestly as you can, as you believe they apply to yourself by circling the number:

1	2	3	4	5	6
Not very well at all					Very well

06	How well can you *finish your homework on time*?	1	2	3	4	5	6
07	How well can you *study* when *there are other interesting things to do*?	1	2	3	4	5	6
08	How well can you *concentrate on your schoolwork*?	1	2	3	4	5	6
09	How well can you *remember information* presented in class and in books?	1	2	3	4	5	6
10	How well can you *arrange a place to study* at home where you won't get distracted?	1	2	3	4	5	6
11	How well can you *motivate yourself* to do schoolwork?	1	2	3	4	5	6
12	How well can you participate in *class discussions*?	1	2	3	4	5	6

Please continue to the other side

~~Below you will find another set of statements.~~ ~~*Again, remember that there are no right or wrong*~~ *answers to these statements.*
Tell us how true or false each statement is for you.

F	*F*	*F*	*T*	*T*	***T***
Definitely false	*Mostly false*	*A little bit false*	*A little bit true*	*Mostly true*	*Definitely true*

13	It is important to me to ***get good grades*** in science.	**F**	F	F	T	T	**T**
14	**I am better at science than the boys *in my class.***	**F**	F	F	T	T	**T**
15	**I am better at science than the boys *in my school.***	**F**	F	F	T	T	**T**
16	Being good in science is ***important to me.***	**F**	F	F	T	T	**T**
17	**I am better at science than the girls *in my class.***	**F**	F	F	T	T	**T**
18	**I am better at science than the girls *in my school.***	**F**	F	F	T	T	**T**
19	I am better at science than all the other students *in my class.*	**F**	F	F	T	T	**T**
20	I am better at science than all the other students *in my school.*	**F**	F	F	T	T	**T**
21	I believe I could be a scientist when I grow up.	**F**	F	F	T	T	**T**
22	I enjoy doing science work.	**F**	F	F	T	T	**T**
23	Doing science work is *interesting* for me.	**F**	F	F	T	T	**T**
24	Compared to others my age, I am good at science.	**F**	F	F	T	T	**T**
25	I get good grades in science.	**F**	F	F	T	T	**T**
26	Science is easy for me.	**F**	F	F	T	T	**T**
27	I am not good at science work.	**F**	F	F	T	T	**T**
28	Learning how to be better in science is easy for me.	**F**	F	F	T	T	**T**
29	I have always done well on science assignments.	**F**	F	F	T	T	**T**
30	I am afraid of doing science when I know it will be graded.	**F**	F	F	T	T	**T**

F	*F*	*F*	*T*	*T*	*T*
Definitely false	*Mostly false*	*A little bit false*	*A little bit true*	*Mostly true*	*Definitely true*

31	I like to do independent science projects.	F	F	F	T	T	T
32	I never seem to be able to understand science.	F	F	F	T	T	T
33	Doing science projects is a lot of fun.	F	F	F	T	T	T
34	Just thinking about science makes me feel nervous.	F	F	F	T	T	T
35	The reason I do science is so that the teacher doesn't think I know less than other students.	F	F	F	T	T	T
36	I want to do better than other students in my science class.	F	F	F	T	T	T
37	I like science assignments I can learn from, even if I make a lot of mistakes.	F	F	F	T	T	T
38	I do my science assignments so others in the class won't think I'm dumb.	F	F	F	T	T	T
39	I would feel successful at science if I did better than most of the other students in the class.	F	F	F	T	T	T
40	An important reason I do my science work is because I like to learn new things.	F	F	F	T	T	T
41	One reason I might not participate in science class is to avoid looking stupid.	F	F	F	T	T	T
42	I would feel really good if I were the only student in class who could answer the teacher's questions about science.	F	F	F	T	T	T
43	I like science assignments that really make me think.	F	F	F	T	T	T
44	One of the main goals in science class is to avoid looking like I can't do my work.	F	F	F	T	T	T
45	I'd like to show my science teacher that I'm smarter than the other students in my science class.	F	F	F	T	T	T
46	Doing better than other students in science class is important to me.	F	F	F	T	T	T
47	I do my science assignments because I am interested in them.	F	F	F	T	T	T
48	An important reason I do my science assignments is so I won't embarrass myself.	F	F	F	T	T	T

Please take one more minute to go back and check to make sure that you have answered <u>every question</u>. <u>Do not leave any blank.</u>

Thank you for your time and honesty!

APPENDIX G
JOURNAL 1 QUESTIONS

ID - from the back of the notecard with your name on it (XXX-XXX-XXX):

Your chemistry teacher's name: choose

Period: period

Journal 1: Group C (red)

Short Answer

Thank you so much for taking the time to reflect on the following questions about how you learn. Your responses will help me better understand what is the *best* learning environment for students. Again, I appreciate your honesty and time.

Each response would be best understood if you could reflect on your personal thoughts for at least 2-3 sentences. Don't worry about grammar or punctuation, I'm interested in your true thoughts – preformatted and straight from the source!

1. ***Please describe your confidence in your ability to pass science class at the end of the semester.*** What grade do you think you will earn? What are your strengths? What are your weaknesses?

2. ***Please describe how well you are able to study when there are other interesting things to do.*** What conditions are best for your learning? What conditions are worst for your learning?

3. ***Please describe what your "ideal" environment for learning looks like.*** For example, do you learn best through classroom discussions, reading alone, study groups with your peers, one-on-one interaction with your teacher, using a computer for research and/or practice, etc. Please feel free to mention another environment that I did not just list.

4. ***How well can you motivate yourself to do schoolwork?*** *What* role(s) do your parent(s)/guardian(s), friends, and teachers play in helping you get your work completed?

5. ***Describe your initial reaction to the computer module you just completed.*** Were there any features of the tutorial that helped you learn? Were there things that you liked or disliked? In your response to this question, please think about how you responded to the other questions in this journal – are there any connections that you see between how you described yourself as a learner and how you felt about this particular computer learning experience?

Thank you for your time. When you hit the submit button, your responses will be sent to me via email. Because of the nature of email, there is a very small chance that your responses might be read by someone else. However, since you have only used your randomly assigned ID and not your name, this should not breach the confidentiality that I have promised as part of this study.

Submit | Reset | Help

ID - from the back of the notecard with your name on it: [ ]

Your chemistry teacher's name [choose ▾]

Period [period ▾]

Journal 1: Group D (blue)

Short Answer

Thank you so much for taking the time to reflect on the following questions about how you learn. Your responses will help me better understand what is the *best* learning environment for students. Again, I appreciate your honesty and time.

Each response would be best understood if you could reflect on your personal thoughts for at least 2-3 sentences. Don't worry about grammar or punctuation, I'm interested in your true thoughts – preformatted and straight from the source!

1. ***Please describe your confidence in your ability to pass science class at the end of the semester.*** What grade do you think you will earn? What are your strengths? What are your weaknesses?
2. ***Please describe how well you are able to study when there are other interesting things to do.*** What conditions are best for your learning? What conditions are worst for your learning?
3. ***Please describe what your "ideal" environment for learning looks like.*** For example, do you learn best through classroom discussions, reading alone, study groups with your peers, one-on-one interaction with your teacher, using a computer for research and/or practice, etc. Please feel free to mention another environment that I did not just list.
4. ***How well can you motivate yourself to do schoolwork?*** What role(s) do your parent(s)/guardian(s), friends, and teachers play in helping you get your work completed?
5. ***Describe your initial reaction to the computer module you just completed.*** Were there any features of the tutorial that helped you learn? Were there things that you liked or disliked? In your response to this question, please think about how you responded to the other questions in this journal – are there any connections that you see between how you described yourself as a learner and how you felt about this particular computer learning experience?

Submit | Reset | Help

ID - from the back of the notecard with your name on it (XXX-XXX-XXX):

Your chemistry teacher's name [choose]

Period [period]

Journal 1: Group E (gold)

Short Answer

Thank you so much for taking the time to reflect on the following questions about how you learn. Your responses will help me better understand what is the *best* learning environment for students. Again, I appreciate your honesty and time.

Each response would be best understood if you could reflect on your personal thoughts for at least 2-3 sentences. Don't worry about grammar or punctuation, I'm interested in your true thoughts – preformatted and straight from the source!

1. ***Please describe your confidence in your ability to pass science class at the end of the semester. What grade do you think you will earn?*** What are your strengths? What are your weaknesses?
2. ***Please describe how well you are able to study when there are other interesting things to do.*** What conditions are best for your learning? What conditions are worst for your learning?
3. ***Please describe what your "ideal" environment for learning looks like.*** For example, do you learn best through classroom discussions, reading alone, study groups with your peers, one-on-one interaction with your teacher, using a computer for research and/or practice, etc. Please feel free to mention another environment that I did not just list.
4. ***How well can you motivate yourself to do schoolwork?*** What role(s) do your parent(s)/guardian(s), friends, and teachers play in helping you get your work completed?
5. ***Describe your initial reaction to the computer module you just completed.*** Were there any features of the tutorial that helped you learn? Were there things that you liked or disliked? In your response to this question, please think about how you responded to the other questions in this journal – are there any connections that you see between how you described yourself as a learner and how you felt about this particular computer learning experience?

Thank you for your time. When you hit the submit button, your responses will be sent to me via email. Because of the nature of email, there is a very small chance that your responses might be read by someone else. However, since you have only used your randomly assigned ID and not your name, this should not breach the confidentiality that I have promised as part of this study.

Submit | Reset | Help

APPENDIX H
JOURNAL 2 QUESTIONS

ID - from the back of the notecard with your name on it (XXX-XXX-XXX): [ ]

Your chemistry teacher's name [choose ▾]

Period [period ▾]

Journal 2: Group C (red)

Short Answer

I want to thank each of you who took the time to give me such valuable input on the last journal response. The time and care that you take with these responses really makes a big difference in how I understand the way you think and learn best - I hope to be a better teacher because of this research!

Here's another short set of questions that are designed to keep expanding my understanding of how high school students learn chemistry. For these questions, please state:

1) **Whether or not the statement is true, false, or somewhere in between.**
2) **Why you feel that way.**

Just like last time, 2-3 sentences should fit the bill for each response - don't fuss over the grammar, spelling, punctuation, etc... just tell me your true thoughts! Thanks lots for your time and care in responding to these questions. I know they can be somewhat personal, but please feel confident that I will maintain your confidentiality, as promised.

1. I get good grades in science.

2. Science is easy for me.

3. I am not good at science work.

4. Learning how to be better in science is easy for me.

5. I have always done well on science assignments.

Now, thinking about the 2nd module that you just completed, please reflect on the following statement. Is it true, false, or somewhere in between? *Why do you feel this way?*

6. Using a computer to review helps me feel more confident that I will do better on future examinations.

Thank you for your time. When you hit the submit button, your responses will be sent to me via email. Because of the nature of email, there is a very small chance that your responses might be read by someone else. However, since you have only used your randomly assigned ID and not your name, this should not breach the confidentiality that I have promised as part of this study.

Submit

ID - from the back of the notecard with your name on it (XXX-XXX-XXX):

Your chemistry teacher's name [choose]

Period [period]

Journal 2: Group D (blue)

Short Answer

I want to thank each of you who took the time to give me such valuable input on the last journal response. The time and care that you take with these responses really makes a big difference in how I understand the way you think and learn best - I hope to be a better teacher because of this research!

Here's another short set of questions that are designed to keep expanding my understanding of how high school students learn chemistry. For these questions, please state:

1) **Whether or not the statement is true, false, or somewhere in between.**
2) **Why you feel that way.**

Just like last time, 2-3 sentences should fit the bill for each response - don't fuss over the grammar, spelling, punctuation, etc.. just tell me your true thoughts! Thanks lots for your time and care in responding to these questions. I know they can be somewhat personal, but please feel confident that I will maintain your confidentiality, as promised.

1. **I get good grades in science.**

2. **Science is easy for me.**

3. **I am not good at science work.**

4. **Learning how to be better in science is easy for me.**

5. **I have always done well on science assignments.**

Now, thinking about the 2nd module that you just completed, please reflect on the following statement. Is it true, false, or somewhere in between? *Why do you feel this way?*

6. **Using a computer to review helps me feel more confident that I will do better on future examinations.**

Thank you for your time. When you hit the submit button, your responses will be sent to me via email. Because of the nature of email, there is a very small chance that your responses might be read by someone else. However, since you have only used your randomly assigned ID and not your name, this should not breach the confidentiality that I have promised as part of this study.

Submit

ID - from the back of the notecard with your name on it (XXX-XXX-XXX):

Your chemistry teacher's name: choose

Period: period

Journal 2: Group E (gold)

Short Answer

I want to thank each of you who took the time to give me such valuable input on the last journal response. The time and care that you take with these responses really makes a big difference in how I understand the way you think and learn best – I hope to be a better teacher because of this research!

Here's another short set of questions that are designed to keep expanding my understanding of how high school students learn chemistry. For these questions, please state:

1) **Whether or not the statement is true, false, or somewhere in between.**
2) **Why you feel that way.**

Just like last time, 2-3 sentences should fit the bill for each response – don't fuss over the grammar, spelling, punctuation, etc... just tell me your true thoughts! Thanks lots for your time and care in responding to these questions. I know they can be somewhat personal, but please feel confident that I will maintain your confidentiality, as promised.

1. I get good grades in science.

2. Science is easy for me.

3. I am not good at science work.

4. Learning how to be better in science is easy for me.

5. I have always done well on science assignments.

Now, thinking about the 2nd module that you just completed, please reflect on the following statement. Is it true, false, or somewhere in between? *Why do you feel this way?*

6. Using a computer to review helps me feel more confident that I will do better on future examinations.

Thank you for your time. When you hit the submit button, your responses will be sent to me via email. Because of the nature of email, there is a very small chance that your responses might be read by someone else. However, since you have only used your randomly assigned ID and not your name, this should not breach the confidentiality that I have promised as part of this study.

Submit

APPENDIX I
JOURNAL 3 QUESTION

ID - from the back of the notecard with your name on it (XXX-XXX-XXX):

Your chemistry teacher's name choose

Period period

Journal 3: Group C (red)

Short Answer

Ok – we are stepping it up a bit.. these questions are focused on something called "science anxiety." Science anxiety is a *very real thing* that many people feel when confronted with science stuff. I am curious to understand what role science anxiety plays in your ability to learn.

Again, I will maintain your confidentiality throughout this entire study and your name will *never be used* in association with your responses. I hope that you will feel safe to answer the following questions with the first thoughts that come to your mind. I really appreciate your cooperation and willingness to improve my own picture of how students think and feel. You are making a difference for future students!

Just like the last two times, I'm looking for 2-3 sentences to get a complete picture of what is going on in your head. Of course, you may write more!

For these questions, please state:

1) **whether or not the statement is true, false, or somewhere in between; and**
2) **why you feel that way.**

1. I am afraid of doing science when I know it will be graded.

2. I never seem to be able to understand science.

3. An important reason I do my science assignments is so I won't embarrass myself.

4. Just thinking about science makes me feel nervous.

5. Sometimes I get so nervous in science that even though I think I know something, I can't remember it when I need it.

And now, thinking about the experiences you have had so far in the computer lab for this unit, please again state:

1. **whether or not the statement is true, false, or somewhere in between; and**
2. **why you feel that way.**

6. I like the fact that no one but me knows whether I got a question right during the computer exercise.

7. The computer feedback helps me feel more confident about my ability to lear.. science.

ID - from the back of the notecard with your name on it (XXX-XXX-XXX): [ ]

Your chemistry teacher's name [choose]

Period [period]

Journal 3: Group D (blue)

Short Answer

Ok – we are stepping it up a bit… these questions are focused on something called "science anxiety." Science anxiety is a *very real thing* that many people feel when confronted with science stuff. I am curious to understand what role science anxiety plays in your ability to learn.

Again, I will maintain your confidentiality throughout this entire study and your name will *never be used* in association with your responses. I hope that you will feel safe to answer the following questions with the first thoughts that come to your mind. I really appreciate your cooperation and willingness to improve my own picture of how students think and feel. You are making a difference for future students!

Just like the last two times, I'm looking for 2-3 sentences to get a complete picture of what is going on in your head. Of course, you may write more!

For these questions, please state:

1) **whether or not the statement is true, false, or somewhere in between; and**
2) **why you feel that way.**

1. I am afraid of doing science when I know it will be graded.

2. I never seem to be able to understand science.

3. An important reason I do my science assignments is so I won't embarrass myself.

4. Just thinking about science makes me feel nervous.

5. Sometimes I get so nervous in science that even though I think I know something, I can't remember it when I need it.

And now, thinking about the experiences you have had so far in the computer lab for this unit, please again state:

1. **whether or not the statement is true, false, or somewhere in between; and**
2. **why you feel that way.**

6. I like the fact that no one but me knows whether I got a question right during the computer exercise.

7. The computer feedback helps me feel more confident about my ability to learn science.

ID - from the back of the notecard with your name on it (XXX-XXX-XXX):

Your chemistry teacher's name [choose]

Period [period]

Journal 3: Group E (gold)

Short Answer

Ok – we are stepping it up a bit.. these questions are focused on something called "science anxiety." Science anxiety is a *very real thing* that many people feel when confronted with science stuff. I am curious to understand what role science anxiety plays in your ability to learn.

Again, I will maintain your confidentiality throughout this entire study and your name will *never be used* in association with your responses. I hope that you will feel safe to answer the following questions with the first thoughts that come to your mind. I really appreciate your cooperation and willingness to improve my own picture of how students think and feel. *You are making a difference for future students!*

Just like the last two times, I'm looking for 2-3 sentences to get a complete picture of what is going on in your head. Of course, you may write more!

For these questions, please state:

1) **whether or not the statement is true, false, or somewhere in between; and**
2) **why you feel that way.**

1. I am afraid of doing science when I know it will be graded.

2. I never seem to be able to understand science.

3. An important reason I do my science assignments is so I won't embarrass myself.

4. Just thinking about science makes me feel nervous.

5. Sometimes I get so nervous in science that even though I think I know something, I can't remember it when I need it.

And now, thinking about the experiences you have had so far in the computer lab for this unit, please again state:

1. **whether or not the statement is true, false, or somewhere in between; and**
2. **why you feel that way.**

6. I like the fact that no one but me knows whether I got a question right during the computer exercise.

7. The computer feedback helps me feel more confident about my ability to learn science.

APPENDIX J
JOURNAL 4 QUESTIONS

ID (XXX-XXX-XXX): Period:

Teacher:

Journal 4: Group C (red)

ShortAnswer

This last set of questions is focused specifically on the feedback given in the computer module. Thank you for taking the time to help me understand how you used the feedback and what it meant to you.

Again, I will maintain your confidentiality throughout this entire study and your name will *never be used* in association with your responses. I hope that you will feel safe to answer the following questions with the first thoughts that come to your mind. I really appreciate your cooperation and willingness to improve my own picture of how students think and feel. You are making a difference for future students!

Just like the times before, I'm looking for 2-3 sentences to get a complete picture of what is going on in your head. Of course, you may write more!

For these questions, please state:

1) whether or not the statement is true, false, or somewhere in between;and
2) why you feel that way.

1. I often guessed in the computer modules without trying to figure out the answer by myself first.

2. The feedback in the computer modules made me feel better about myself and my ability to learn chemistry.

3. When I got questions wrong in the chemistry modules, the feedback made me feel worse.

4. The feedback in the computer modules helped me learn the chemistry concepts better.

5. I liked the feedback provided in the computer modules.

ID (XXX-XXX-XXX):

Period:

Teacher:

Journal 4: Group D (blue)

ShortAnswer

This last set of questions is focused specifically on the feedback given in the computer module. Thank you for taking the time to help me understand how you used the feedback and what it meant to you.

Again, I will maintain your confidentiality throughout this entire study and your name will *never be used* in association with your responses. I hope that you will feel safe to answer the following questions with the first thoughts that come to your mind. I really appreciate your cooperation and willingness to improve my own picture of how students think and feel. You are making a difference for future students!

Just like the times before, I'm looking for 2-3 sentences to get a complete picture of what is going on in your head. Of course, you may write more!

For these questions, please state:

1) whether or not the statement is true, false, or somewhere in between; and
2) why you feel that way.

1. I often guessed in the computer modules without trying to figure out the answer by myself first

2. I listened to all the feedback given when I got the answer correct.

3. The feedback in the computer modules made me feel better about myself and my ability to learn chemistry.

4. When I got questions wrong in the chemistry modules, the feedback made me feel worse.

5. The feedback in the computer modules helped me learn the chemistry concepts better.

6. I liked the feedback provided in the computer modules.

ID (XXX-XXX-XXX):

Period:

Teacher:

Journal 4: Group E (gold)

ShortAnswer

This last set of questions is focused specifically on the feedback given in the computer module. Thank you for taking the time to help me understand how you used the feedback and what it meant to you.

Again, I will maintain your confidentiality throughout this entire study and your name will *never be used* in association with your responses. I hope that you will feel safe to answer the following questions with the first thoughts that come to your mind. I really appreciate your cooperation and willingness to improve my own picture of how students think and feel. You are making a difference for future students!

Just like the times before, I'm looking for 2-3 sentences to get a complete picture of what is going on in your head. Of course, you may write more!

For these questions, please state:

1) whether or not the statement is true, false, or somewhere in between; <u>and</u>
2) why you feel that way.

1. I often guessed in the computer modules without trying to figure out the answer by myself first.

2. I listened to all the feedback before going on to another choice.

3. The feedback in the computer modules made me feel better about myself and my ability to learn chemistry.

4. ~~When I got questions wrong in the chemistry modules, the feedback made me feel worse.~~

5. The feedback in the computer modules helped me learn the chemistry concepts better.

6. I liked the feedback provided in the computer modules.

APPENDIX K
INTERVIEW QUESTIONS

From the perspective of a student, describe a good learning experience:

- in a classroom
- using a computer by yourself

What types of things or experiences make you feel more confident about your ability to learn science?

What types of things or experiences make you feel less confident about your ability to learn science?

Describe how you used the computer modules. I'm interested in how you approached each question and how you reacted when you got a question correct? Incorrect?

APPENDIX L
CHEMISTRY UNIT OBJECTIVES

15-1: What are acids and bases?
15-2: Can the strengths of acids and bases be quantified?
15-3: How are acidity and pH related?
15-4: What is a titration?

Sub-objective

15-1.1: Describe the distinctive properties of acids and bases
15-1.2: Distinguish between the terms strong and weak as they apply to acids and bases
15-1.3: Explain the unusually high electrical conductivities of acidic solutions
15-1.4: Name and describe the functional groups that characterize organic acids and bases
15-1.5: Use K_w to calculate a solution's hydronium ion or hydroxide ion concentration
15-2.1: State the Bronsted-Lowry definitions of an acid and a base
15-2.2: Differentiate between monoprotic, diprotic, and triprotic acids
15-2.3: Write chemical equations showing how an amphoteric species can behave as both an acid and a base
15-2.4: Identify conjugate acid-base pairs
15-2.5: Calculate K_a from the hydronium ion concentration of a weak acid solution
15-3.1: State the definition of pH and explain the relationship between pH and H_3O^+ ion concentration
15-3.2: Perform calculations using pH, $[H_3O^+]$, $[OH^-]$, and quantitative descriptions of aqueous solutions
~~15-3.3: Describe two methods of measuring pH~~
15-3.4: Describe how a buffer solution is able to resist changes in pH
15-4.1: Write an ionic equation for a neutralization reaction, and identify its reactants and products
~~15-4.2: Describe the conditions at the equivalence point in a titration~~
15-4.3: Tell how a buret is used in a titration
15-4.4: Discuss two methods used to detect the equivalence point in a titration
15-4.5: Explain how you would select an indicator for an acid-base titration
15-4.6: Calculate the unknown concentration of an acid or base using titration data

APPENDIX M
THREE-WEEK SYLLABUS

April 5th: I will visit all classes and give a quick spiel about the research, distribute permission forms, envelopes, and set up ID sticker envelopes. This will take about 15 minutes.

Each day that week, please collect their envelopes with the forms sealed inside. They should have their name (neatly printed) and one ID sticker on the outside of the envelope. I will pick up your envelopes on Friday and make a list of those students who still need to turn them in. All envelopes need to be collected by Tuesday, 04/13/04.

1 04/12/04 M	• Kinetics – tie in to How to Get a Date for Prom	
2 04/13/04 T	• SS Lab: Factors affecting the rate of a chemical reaction (SS24)	Work on lab questions
3 04/14/04 W	• Pretests: Acids & Bases/SE • Handout CB setups	CB Ch 15 pp 1, 3, 5
4 04/15/04 R	• HF Article • SS Lab: A small-scale colorimetric pH meter (SS26) • Comp 1-2: Properties of acids/bases	CB Ch 15 pp 7, 9, 11
5 04/16/04 F	• ~~SS Lab: Strong and weak acids and bases (SS28)~~ • Comp 3-4: Strong vs. weak, Electrical conductivities ○ Demo: H^+ vs. Na^+ conductivities and CBL	~~Finish questions to SS26 and SS28~~ CB Ch 15 pp 13,15, 17
6 04/19/04 M	**Computer Lab: Module 1 (15.1)**	CB Ch 15 pp 19, 21, 23
7 04/20/04 T	• Comp 5-6: Functional groups • Comp 7-8: K_w calculations • Comp 9-10. Bronsted-Lowry Definition	SR pg 549 1-8

8
04/21/04
W
	• Go over homework
	• Comp: 11-12. Mono-, di-, and tri-protic acids
	• Comp 17-18: Amphoterism
	• Comp 19-20: Conjugate Acid-Base Pairs
	• Discuss lab: Applying Bronsted/Lowry to SS28
	    • Reactions for all experiments
	    • Label acid, base, conj acid, conj base $[H_3O^+]$,$[OH^-]$
	    • Answer Questions: a-e
		BC 4, 5, 22

9 04/22/04 R	**Computer Lab: Module 2 (15.2)**	Work on labs
10 [illegible] F	• Finish comp 23-24: pH introduction • Comp 25-26. More pH calculations • Comp 21-22. K_a of weak acids	Work on labs CB 25, 27, 29
11 04/26/04 M	**Computer Lab: Module 3: (15.3 + review)**	SR pg 567: 6-10 BC: 31-36
12 04/27/04 T	ACT prep	CB pp 31, 33, 35, 37
13 04/28/04 W	ACT – Work day	N/A

14
04/29/04
R
	• Comp: 27-28: Indicators
	    ○ Demo: Dry ice and UI
	• Comp 29-30: Buffers
	    ○ Demo: CBL's and Buffer Capacity
	• Comp 31-32: What is a titration?
	• Comp 33-34. Equivalence point in a titration
	• Comp 35-36: Using a buret
		CB pp 39, 41, 43

15 04/30/04 F	• Comp 37-38: Detecting equivalence point. • Comp 39-40: Selecting an indicator • Comp 41-42: Titration calculations (Last page of chapter) • Introduce large-scale lab, discuss prelab expectations	Prelab
16 [illegible] M	**Computer Lab: Module 4 (15.4)**	Prelab
17 05/04/04 T	Large scale lab – day 1	Complete lab calculations from day 1
18 [illegible] W	Large scale lab – day 2	Finish lab – due Friday
19 05/06/04 R	**Wrap up all, review for exam**	Finish lab, study for test
20 05/07/04 F	Posttests	

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