PODCAST EFFECTIVENESS AS SCAFFOLDING SUPPORT FOR STUDENTS ENROLLED IN
FIRST-SEMESTER GENERAL CHEMISTRY LABORATORIES

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Podcasts covering essential first-semester general chemistry laboratory techniques and central concepts that aid in experimental design or data processing were prepared and made available for students to access on an as-needed basis on iPhones or iPod touches. Research focused in three areas: the extent of podcast usage, the numbers and types of interactions between instructors and research teams, and student performance on graded assignments. Data analysis indicates that the podcast treatment research teams accessed a podcast 2.86 times on average during each week that podcasts were available. Comparison of interaction data for the lecture treatment research teams and podcast treatment research teams reveals that interactions with instructors were statistically significantly fewer for teams that had podcast access rather than a pre-laboratory lecture. The implication of the results is that student research teams were able to gather laboratory information more effectively when it was presented in an on-demand podcast format. Finally, statistical analysis of data on student performance on graded assignments indicates no significant differences between outcome measures for the treatment groups when compared as cohorts. The only statistically significant difference is between students judged to be highly motivated; for this sub-group the students in the podcast treatment group earned a course average that was statistically significantly higher than those in the lecture treatment group.
This research study provides some of the first data collected on the effectiveness of podcasts delivered as needed in a first-semester general chemistry laboratory setting.
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CHAPTER I

INTRODUCTION

Chemistry is a laboratory science. Learning chemistry means not only learning facts and concepts that describe the physical world on an atomic level, but also learning how to examine the physical evidences of chemical principles in a laboratory setting. The teaching laboratory is the standard method of training students in skills central to scientific investigation. Some of the first laboratory courses were taught at the German universities of Göttingen, Landshut and Jena as early as 1806 (Lockemann & Oesper, 1953). However, it is Justus von Liebig who was a professor at the University of Giessen in Germany during the 1820s that is credited with advancing the concept of teaching chemistry through prescribed laboratory activities (Elliott, 2006; Lockemann & Oesper, 1953). He planned a curriculum that included a series of chemical analyses of known substances to train students in analytical methodology. Students who completed the prescribed analysis of known substances continued the training by testing unknown samples. Liebig described his format in a published laboratory manual that was widely used in European universities (Elliott, 2006). Teaching through laboratory courses became a central portion of university science training in Europe.

Nearly forty years later Francis H. Storer and Charles W. Eliot published the renowned chemistry laboratory textbook *A Manual of Inorganic Chemistry Arranged to Facilitate the Experimental Demonstration of the Facts and Principles of the Science* (Davis, 1929; Nakhleh, Polles, & Malina, 2002). These men taught the first chemistry laboratory courses at Massachusetts Institute of Technology and were two of the ten faculty members of the institute at the time of their hire. The preface to the first edition of their book begins with this
statement: “In preparing this manual, it has been the author’s object to facilitate the teaching of chemistry by the experimental and inductive method” (as quoted by Davis, 1929, p. 876). Their text and model curriculum had a major impact on the continuing advancement of chemistry laboratory teaching particularly in the United States.

At the close of the 19th century, prominent universities began requiring laboratory courses taught at the secondary level as pre-requisites for admission as well as incorporating laboratory courses in their own curricula (Nakhleh et al., 2002). The teaching laboratory quickly became entrenched as a standard science teaching methodology and university degree programs in the sciences were developed that included many laboratory course requirements (Hofstein, 2004; Hofstein & Mamlock-Naaman, 2007; Kirschner & Meester, 1988; Nakhleh et al., 2002). The largest scientific society worldwide is the American Chemical Society (ACS) and in their published guidelines for program approval and student certification, they prescribe that bachelor’s degree programs in chemistry or biochemistry include 400 hours of laboratory instruction beyond the introductory chemistry laboratory (American Chemical Society, 2008). With so much emphasis placed on training future chemists in a teaching laboratory setting, determining methods for effective laboratory teaching is essential.

The Statement of the Problem

The Challenge of Effective Laboratory Pedagogy

A considerable amount of research has been focused on the development of laboratory teaching pedagogies and appropriate goals for laboratory instruction (Abraham et al., 1997; Aukszi et al., 2002; Berg, Bergendahl, & Lundberg, 2003; Buntine et al., 2007; Cacciatore & Sevian, 2009; Cooper & Silberman, 2000; Elliott, 2006; Jalil, 2006; Niedderer & Dimitris, 2002;
Poock, Burke, Greenbowe, & Hand, 2007). While there is no clear consensus on the best teaching approach for undergraduate chemistry laboratories, the movement in chemistry education is toward pedagogies that promote student engagement in the learning process and that encourage student independence while building critical thinking skills (Hofstein & Mamlock-Naaman, 2007; Johnstone & Al-Shuaili, 2001; Olson & Loucks-Horsley, 2000). Laboratory instruction pedagogies can be broadly categorized into three instruction styles: expository instruction, problem-based instruction, and inquiry-based instruction (Elliott, 2006; Kelly & Finlayson, 2007).

In a laboratory taught with an expository style students are required to use deductive reasoning skills. The objectives of an experiment are clearly stated, a detailed procedure is provided for students to follow and the student goal is to reproduce an expected outcome that verifies a chemical principle or process. This is the traditional method of teaching laboratory courses and is still the most common approach for chemistry laboratories taught at undergraduate institutions (Abraham et al., 1997; Hofstein, 2004). It is also an approach that has been widely criticized because students can successfully complete laboratory exercises with very little understanding of relevant chemistry concepts (Garratt, 1997; Garratt, 2002; Hunter, Wardell, & Wilkins, 2000; Johnstone, 1997; Johnstone, Sleet, & Viannna, 1994).

A second laboratory instruction style is problem-based instruction. Laboratories taught with a problem-based approach present students with a real-world chemically related problem. Some curricula written in a problem-based format present problems that are very open-ended and others present problems narrower in focus with specific desired outcomes. Students work in teams to determine approaches to solving the problem deductively through chemical
investigation; all procedures are student generated (Kelly & Finlayson, 2007). Often, problem-based experiments are multi-week projects. Goals of problem-based instruction are to simulate a research environment and engage students by allowing them to experience applied chemistry as well as encouraging critical thinking.

Laboratories taught with an inquiry-based curriculum (alternatively called inquiry-driven curriculum) require students to use inductive reasoning and to generate all or parts of an experimental procedure independently with the goal of helping students connect laboratory experiences with chemistry concepts (Prince & Felder, 2007). Inquiry-based experiments have also gained a reputation as being a useful method for engaging students while enhancing critical thinking skills (Cacciatore & Sevian, 2009; Minner, Levy, & Century, 2009). A growing interest in inquiry-based curriculum has resulted in an assortment of published experiments that are designated as inquiry-based, but among these there is great variation in the amount of information provided for the students and the amount of independent work required (Martin-Hansen, 2002). Some inquiry-based laboratories are strongly guided by instructors and curriculum, but others are very open-ended. Fay and coworkers have published a rubric for evaluating inquiry experiments according to the extent of independence required by the activity in an effort to help standardize the classification of experiments by level of inquiry (Fay, Grove, Towns, & Bretz, 2007).

In addressing appropriate pedagogies for chemistry laboratory instruction, the ACS guidelines offer these encouragements (American Chemical Society, 2008, p. 8):

Faculty should incorporate pedagogies that have been shown to be effective in undergraduate chemistry education. Examples include problem- or inquiry-based learning, peer-led instruction, group learning, learning communities or networks, writing throughout the curriculum, and technology-aided instruction. Laboratory work provides
a particularly attractive opportunity for inquiry-driven and open-ended investigations that promote independent thinking, critical thinking and reasoning, and a perspective of chemistry as a scientific process of discovery.

The ACS assessment of inquiry-driven (inquiry-based) investigations and open-ended investigations (may include problem-based learning or open-ended inquiry-based activities) as an effective method for teaching is not universally endorsed. Some instructors attempt inquiry-based instruction and abandon it because of the unique challenges involved in implementing less structured curriculum (Fay & Bretz, 2008; Mullins, 2010). At times, laboratories taught with an inquiry-driven or open-ended format leave students feeling confused (Berg et al., 2003; Germann, 2006; Kirschner, Sweller, & Clark, 2006). While instructor support can be important in any teaching laboratory, the success of inquiry-based or problem-based instruction can depend heavily on the skill with which an instructor facilitates the work of student groups in the laboratory (Bruck & Towns, 2009; Collins, Brown, & Newman, 1989; Hmelo-Silver, Duncan, & Chinn, 2007; Hofstein & Lunetta, 2004; Johnstone, 1997). For this reason, adequate training of instructors or teaching assistants in implementing inquiry-based pedagogies is essential (Hofstein & Lunetta, 2004; Krystyniak & Heikkinen, 2007).

The Challenge of Supporting Students through Curriculum

The instructor provides a central supporting role in a teaching laboratory, but multiple curricular supports or scaffolds can be distributed in the learning environment that allow open-ended and inquiry-based curricula to be used with greater success (Puntambekar & Kolodner, 2005; Quintana et al., 2004). Important curricular supports include a structured organization of the methodology, gradual introduction of increasingly independent activities, laboratory software programs and a preparation of students for participation by assuring that they have
essential background knowledge (Bruck & Towns, 2009; Hmelo-Silver, 2006; Quintana et al., 2004). A structured organization helps students move through an inquiry exercise by providing a predictable workflow. A gradual increase in responsibility for planning experimental procedures allows students to acclimate to a methodology that requires independence. Collection of data using computer software and computer interfaced sensors allows students to see data graphically as a chemical process proceeds. This in situ data analysis can help students connect the results with the physical reality of the experiment (Hofstein & Lunetta, 2004).

Assuring that all students have essential background knowledge can be the most challenging of the curricular supports or scaffolds to provide. Students must have some basic manipulative skills and a familiarity with common experiment protocol in order to be successful in a university level laboratory taught with any type of curriculum (Garratt & Bailey, 2002). This becomes a more critical issue when the students are responsible for independently generating appropriate procedures (Bruck & Towns, 2009). Due to the variety of student high school laboratory experiences, an instructor teaching an entry-level university course has the unique challenge of needing to provide training for students who have had limited laboratory experience and students who have had strong laboratory experience while keeping all of the students engaged in the learning process (Garratt & Bailey, 2002). The volume of new information needed to perform an experiment may overwhelm students with limited laboratory experience. The failure to support students through adequate preparation for the learning environment leads to discouragement for both instructors and pupils (Bruck & Towns, 2009; Johnstone, 1997).
Opportunities to Provide Additional Support for Laboratory Students

A method of providing essential background information in a format that students could access as needed could be a valuable addition to a laboratory curriculum. If podcasts on pertinent chemistry laboratory topics were prepared and made available on a mobile platform, then students could retrieve a podcast covering a specific topic they needed to learn or review. A student could watch and listen to the presentation several times, if needed. In larger laboratory programs that employ many teaching assistants podcasts of this type might help standardize the background support provided for students. This study investigated the usefulness of pertinent chemistry laboratory podcasts delivered via iPhones® or iPod touches® as a support for students working in a laboratory course using an inquiry-based curriculum. The extent to which students used the podcasts was investigated, as well as the effects of podcast access on interactions between the instructors and students during the laboratory sessions and on the performance of students on graded laboratory assignments.

Course Selected for Study

The course selected for use as a research sample met several important requirements: (a) it was a first-semester general chemistry laboratory course primarily populated by entering freshmen students, (b) there were multiple sections led by the same instructor, (c) the curriculum was in an inquiry-based format and (d) there was adequate saturation of mobile devices. Six sections of a general chemistry laboratory course taught at Abilene Christian University (ACU) were selected as the research sample. Internal Review Board (IRB) approval was obtained through the boards at both ACU and University of North Texas (UNT) (see
Appendix A for executed documents). The curriculum of the course is described in the Methodology chapter.

Purpose of the Study

The purpose of this study was to analyze the effectiveness of podcasts that were accessed as needed on a mobile learning device by students working in a laboratory taught with an inquiry-based curriculum. The podcasts covered topics that students needed as background knowledge for successful participation in the laboratory experiments. The information contained in the podcasts is traditionally taught in a lecture format at the beginning of the laboratory session. Information may be too dense for some students to fully comprehend and it may be so familiar that other students lose interest and miss important details. The availability of the podcasts may be a resource that allows students to gather the information when they need it and allows students to work more independently during laboratory sessions.

Two treatment groups were selected: one group received a pre-laboratory lecture and the other group had access to podcasts covering the same information presented in the lecture. Data was collected on the extent of podcast usage for the podcast treatment group. Data on the type, number, and topic of interactions between instructors and students during the laboratory sessions and the performance of students on laboratory assignments were collected for both the podcast treatment group and the lecture treatment group. Statistical comparison of the data from the two treatment groups may elucidate any relationship between the method of information delivery and interactions between instructors and students or student performance.
Research Questions

*Research Question 1:* When relevant chemistry podcasts are available for on-demand access during a general chemistry laboratory taught with an inquiry-based curriculum, how frequently will student research teams access them?

*Research Question 2:* What differences are evident in the number, types, and topics of scaffolding interactions between student research teams and instructors in laboratory sections that have access to on-demand podcasts but no pre-laboratory lecture and those who have been instructed using a traditional pre-laboratory lecture?

*Research Question 3:* What do the student outcome measures of laboratory report grade average, laboratory quiz average, laboratory final exam grade and laboratory course average indicate about performance differences between students who have access to the on-demand podcasts versus students who have received the same information in a traditional lecture format?

Definition of Terms

*American Chemical Society (ACS):* A scientific association of professional chemists. The ACS certifies programs at universities that meet set curriculum standards.

*Clarifying interactions:* A discussion between student research teams and an instructor through which the instructor provides assistance to help the team accomplish their experimental goals and encourage them to successfully complete their activity.

*Expository instruction:* Traditional lecture style teaching pedagogy.
Follow up interaction: A discussion between student research teams and an instructor through which an instructor attempts to guide the student team to a new level of understanding connecting with ideas from previous experiments or related concepts.

Guided inquiry: A classroom pedagogy that uses inquiry-based activities coupled with instructor guidance to move students through the construction of scientific principles.

Instructor: A faculty member responsible for leading a laboratory section or a teaching assistant responsible for assisting in a laboratory section.

Inquiry: A classroom pedagogy in which the students work independently or in teams to construct or discover scientific principles.

iPhone®: A mobile device manufactured by Apple® that is an Internet-enabled phone that has functions of a mobile phone, wireless Internet device and iPod touch® (see below)

iPod touch®: A mobile device manufactured by Apple® that is a wireless Internet device with audio and video playback features.

Level of inquiry: The extent to which students are required to work independently in suggesting questions to investigate, designing their own experiments and interpreting the results.

Outcome measures: Graded assignments for the sample laboratory course.

Podcast: A digital audio or video presentation in a file that is easily played on demand on a computer or personal device like an iPhone® or iPod touch®.

Podcast access event: A record of an enrolled student accessing a laboratory podcast during the laboratory period.
**Reflection:** A written response to a laboratory activity that includes the student’s understanding of the activity’s conceptual integration into chemistry principles and any questions that the student may have in response to the activity.

**Scaffolding:** Providing support to students learning a new laboratory skill or concept.

**Scaffolding interaction:** During laboratory, a discussion between an instructor and student that is centered on the topic of the experiment and that may be initiated by either the student team spokesperson or by the instructor.

**Science writing heuristic:** A pedagogy incorporating collaborative inquiry activities, cooperative negotiation of conceptual understanding, and individual writing and reflection.

**Student research team:** Three or four students assigned to work in a laboratory as a team through each part of the laboratory curriculum.

**Significance of the Study**

The study of methods of providing support for students and instructors in a laboratory taught with an inquiry-based curriculum using mobile devices is important for several reasons. During the past decade, science education has been closely examined at the national level. Standards for teaching and learning have been formulated with the intended goal of spurring widespread reform (Olson & Loucks-Horsley, 2000). Inquiry-based laboratories and activities are a central theme in the National Science Education Standards published by the National Research Council (Olson & Loucks-Horsley, 2000). Research on methods of successfully implementing inquiry-based curriculum in laboratories and classrooms is needed to help direct reform in a practical way.
In their 2007 review of the state of laboratory teaching, Hofstein and Mamlock-Naaman suggested that specific research that focuses on the details of curricular support and student interactions with instructors during laboratory activities would help advance a thoughtful analysis of teaching pedagogies (Hofstein & Mamlock-Naaman, 2007). The complexity of interactions between students and instructors and implementation of pedagogies must be thoroughly described in literature to provide a more complete understanding of best teaching practices based on research.

Podcasts provided on demand as a support for students during laboratories have not been fully investigated. The mobile technology that will make this type of student support readily available in many classrooms is new, but quickly becoming common. Software for easy preparation of podcasts has become available in the past few years and this makes the proposed teaching platform accessible to any instructor with a digital camera and computer access. This study may help determine if podcasts delivered on a mobile device are effective as a student support during laboratories and what effects podcast usage has on interactions between students and instructors during laboratory sessions.
CHAPTER II

LITERATURE REVIEW

Introduction

New technologies have great promise for providing educational support that may allow students to learn more effectively and in more meaningful ways. Technology-based tools must be part of a coherent pedagogical approach if they are to be effective and educators must consider the ways students learn in the design of technology-supported curriculum (Bransford, Brown, & Cocking, 2000). This chapter reviews the research literature in the areas of the cognitive apprenticeship theory (Collins et al., 1989) as it relates to chemistry instruction, modeling, coaching and scaffolding as teaching methods, the use of video and podcast instruction in chemistry laboratory curriculum and the use of mobile devices as learning tools.

A Theoretical Perspective: Cognitive Apprenticeship

A theoretical basis for understanding teaching and learning helps inform interpretation of education research findings. Investigating how and when an educational practice works is important, but equally important is the theoretical underpinning that offers an explanation for why the practice is or is not effective (Abraham, 2007). Understanding the reasons for success or failure can lead to a more intentional development of effective educational practices.

The cognitive apprenticeship theory is a learning model that can be used to explain the relationship between a laboratory instructor and student as the student is trained in laboratory techniques and appropriate laboratory procedures including manipulative and cognitive processes (Berry, 2000; Collins, 1991; Collins et al., 1989; Elliott, 2006; Jones & Dorneich, 1997; Lagowski & Stewart, 2003; Quintana et al., 2004). This theory compares academic training to a
traditional apprenticeship in a trade such as tailoring or carpentry. It is consistent with a constructivist view of learning and posits that a novice learns by observing and imitating the behavior of an expert (Collins, 1991; Collins et al., 1989).

Figure 1 shows the four dimensions identified as being part of teaching and learning through cognitive apprenticeship. The content dimension includes four components (Lagowski & Stewart, 2003):

1. Important conceptual and factual knowledge of a discipline
2. Heuristic strategies or “tricks of the trade”
3. Techniques essential for controlling work within the discipline
4. Strategies for learning the domain knowledge

Together these components represent the information that the expert must pass on to a novice during training. The sequence dimension describes the order used in the teaching process and suggests that an instructor should begin training a student by helping them acquire a global understanding of the discipline before moving to more specific skills and concepts with increasing complexity and diversity (Lagowski & Stewart, 2003). The sociology dimension describes the social setting of the learning situation (Collins, 1991; Collins et al., 1989; Ghefaili, 2003). The culture of practice, cooperative and competitive structures, and factors that involve students to lead to intrinsic motivation will all influence the learning process (Lagowski & Stewart, 2003).
The dimension of methods focuses on the approach to teaching which is vital to any instruction pedagogy. The sub-categories within the methods dimension can be viewed as a set of three actions initiated by the instructor or curriculum (shown in red in Figure 1) and three actions completed by the student (Ghefaii, 2003). The instructor in the apprenticeship relationship models a laboratory process that can fall in the cognitive or manipulative realm. As the student learns to utilize the laboratory process, the instructor fills a coaching role as they remind the student of important aspects of the process and may clarify details. Then as the student becomes more adept at performing the technique or cognitive process, the instructor
supports them by providing scaffolding instruction and eventually fades or withdraws support as the student becomes more proficient (Collins, Brown, & Holum, 1991; Collins et al., 1989). In this manner a novice may accomplish tasks that may have been just beyond their ability level if attempted without support. Vygotsky described this as being in the zone of proximal development (ZPD) and proposed that teaching and learning are most productive in this zone (Vygotsky, 1978). Through the three-fold modeling, coaching, scaffolding with fading process students learn how to perform a task and learn why it is performed in the prescribed manner (Hmelo-Silver et al., 2007).

A theory of modeling outlined by Bandura suggests some requirements for successful modeling (Bandura, 1997). First, the student must have access to the essential information required for the target skill and be able to retain that information. Second, retention requires that the student be attentive and motivated to learn. According to Bandura, the measure of modeling success is the student’s independent reproduction of the target skill (Bandura, 1997).

The second triad of activities that comprise the methods dimension of cognitive apprenticeship may be initiated by the instructor, but the tasks are performed by the student: (1) articulation of acquired understanding, (2) reflection on comparisons between new understanding and previous knowledge, and (3) exploration of new avenues of investigation (Lagowski & Stewart, 2003). This is the process that laboratory instructors hope to lead students through by requiring a laboratory report or research advisors expect from graduate students preparing presentations for a conference (Lagowski & Stewart, 2003; Poock et al., 2007). New skills and knowledge are integrated into the student’s knowledge base and through repetition of instruction and articulation followed by reflection and exploration the novice
student builds the foundation necessary for becoming an expert (Lawson, Abraham, & Renner, 1989). Teaching and learning through cognitive apprenticeship is student-centered; the student constructs a knowledge base through experiential training (Collins et al., 1989; Kim, 2005; Lui & Matthews, 2005).

There are several imbedded assumptions in the cognitive apprenticeship theory that are pertinent to this study. First, there is an assumption of extensive interaction between the expert and the novice in the teaching processes that comprise the methods dimension (Edmondson, 2005). The ideal of personalized response and encouragement is a realistic one for training of new graduate students in a research laboratory where a research advisor or more experienced graduate student may train one to three students (Lagowski & Stewart, 2003). Most undergraduate teaching laboratories, however, have an instructor to student ratio closer to one instructor to twenty-five students. This ratio can challenge the assumptions of the cognitive apprenticeship theory as a model of instruction in the teaching laboratory. Curriculum must be carefully planned to incorporate the essential interactions between instructor and student.

Second, it is important to note that true apprenticeship occurs in the context of the activity being taught. Modeling or demonstration of a process out of immediate context will not have the same effect as modeling in the activity setting (Collins et al., 1989; Herrington & Oliver, 2000). In a laboratory setting, it could be argued that a laboratory lecture covering a technique or procedure that occurs before the students enter a laboratory to work with equipment or perform cognitive tasks cannot provide authentic apprenticeship support. A skill demonstrated with great accuracy and clarity, out of context, provides students with
information that they must be able to retain until a later time (Bandura, 1997). For students
who must grasp new information beyond their level of competency, continued support is
essential (Collins et al., 1991; Collins et al., 1989; Vygotsky, 1978). Vehicles for effective
modeling, coaching and scaffolding must be provided in a well-planned laboratory curriculum.

The cognitive apprenticeship theory has been used to describe the process of learning in
a variety of disciplines (Dennen, 2003). Training in a chemistry laboratory very closely parallels a
traditional apprenticeship approach that involves an expert instructor who models
manipulative and cognitive processes for students (Berry, 2000; Lagowski & Stewart, 2003). The
important apprenticeship tasks of modeling, coaching and providing scaffolding instruction as
the students learn allows them to accomplish tasks that would not be possible without expert
support (Vygotsky, 1978). Learning is situated within an environment of laboratory activity and
is mediated by interaction among the students and instructor (Bransford et al., 2000; Nakhleh
et al., 2002). As curriculum is developed to teach a chemistry laboratory, the methods of
cognitive apprenticeship can provide a framework for planning effective teaching strategies.

**Modeling, Coaching and Scaffolding**

The methods dimension of the cognitive apprenticeship theory identifies three key
requirements for training a student through apprenticeship: modeling, coaching and scaffolding
with fading (Collins et al., 1991; Collins et al., 1989; Dennen, 2003; Lagowski & Stewart, 2003).
Modeling can be defined as demonstrating a process for the purpose of teaching an observer to
reproduce it (Dennen, 2003). The demonstrated process may include manipulative and
cognitive components (Jonassen, 1999). As noted earlier, Bandura’s theory of modeling
emphasizes the importance of a learner’s motivation, attentive observation, access to
information and ability to retain information for successful modeling to occur (Bandura, 1997). Modeling is a first step in providing the essential base of knowledge that a student will need to successfully complete a laboratory experiment or activity.

After a process has been demonstrated through modeling, teaching continues through coaching and scaffolding (Puntambekar & Kolodner, 2005; Quintana et al., 2004). The terms coaching and scaffolding are undifferentiated by some researchers, but discussed as distinct activities by others (Dennen, 2003). Collins (1991) envisioned coaching as overseeing student work and scaffolding as a function of coaching. McLoughlin (2002) describes scaffolding as the primary function and coaching as an activity through which scaffolding is accomplished. Whether coaching or scaffolding is defined as the primary support task, it is universally understood that the purpose of scaffolding and/or coaching is to continue training the student or novice in learning of concepts, strategies, metacognitive skills and procedures (Dennen, 2003; McLoughlin, 2002). Through traditional scaffolding a more experienced instructor assists the student in accomplishing tasks that would be unattainable without expert assistance and expands their knowledge base (Wood, Bruner, & Ross, 1976).

Scaffolding or coaching is only effective if the student is capable of performing the target task with the appropriate support. Assuring that instruction is within the student’s ZPD is essential for success (Vygotsky, 1978). In a discussion of scaffolding Dennen notes (Dennen, 2003, p. 815):

The ZPD is a critical concept to consider when providing scaffolding. Scaffolding affects learners both cognitively and emotionally, impacting not just learner skill and knowledge, but also learner motivation and confidence when approaching a task ... these successes rely on scaffolding that is directed appropriately at the learner’s current ability level. In other words, it must occur within the learner’s ZPD.
Successfully scaffolding students with varied ZPD levels requires accommodation for differences in academic preparation of individual students in order to provide appropriate support (White & Frederiksen, 1998).

What practical forms might scaffolding take? Scaffolding might be offered through a directive approach initiated by an instructor who intervenes in student activity to teach a particular skill or through a supportive approach more tailored to the individual student’s progress (Lenski & Nierstheimer, 2002). Directive scaffolding can be delivered as students encounter the need to know new information; the in-context delivery of direct instruction is more effective than a lecture delivered before a student understands the necessity of the information (Edelson, 2001). Supportive scaffolding may entail discussing a process with students to assist them in articulating new information that may help students connect their developing understanding with previous knowledge (Hmelo-Silver et al., 2007). Structures such as chronological task templates or prompts that remind students to use certain strategies provided through curriculum can scaffold student organization of knowledge (Quintana et al., 2004; Sandoval & Reiser, 2004). As a learner becomes proficient at performing the target task, scaffolding and coaching should diminish. The process of fading should be the natural conclusion of successful apprenticeship as the student gains competence and is no longer dependent on the instructor’s support (Ghefaili, 2003; Puntambekar & Hubscher, 2005).

The use of computer software to model, coach and scaffold learning is an area of intense research. Collins (1991) recognized the difficulty of providing extensive personal attention in a classroom setting and suggested that technology could play a vital role in making apprenticeship teaching a reality. He stated, “technology enables us to realize apprenticeship
learning environments that were either not possible or not cost effective before” (Collins, 1991, p. 1). Over the past two decades many adaptive software programs have been developed for use in education. Some examples are tutoring and homework programs that provide individual feedback, “micro-worlds” that mimic real world situations and can provide a type of situated learning, and programs that provide expert modeling or modeling of usually invisible processes such as atomic motion or functioning of internal organs (Aukszi et al., 2002; Charlesworth & Vician, 2003; Quintana et al., 2004; Cole & Todd, 2003; Collins, 1991; Edelson, 2001; Elliott & Lira, 2008; Fyneweever, 2008; Keeney-Kennicutt, 2007; Koehler & Orvis, 2003; Novak, Patterson, Garvin, & Christian, 1999; Puntambekar & Kolodner, 2005; Toth, Suthers, & Lesgold, 2002; White & Frederiksen, 1998; Williamson & Cracolice, 1995). Research on the effectiveness of computer-assisted instruction indicates that many software programs provide a rich environment for deep learning (Murray, Blessing, & Ainsworth, 2003). Effective modeling, coaching and scaffolding with fading are components of teaching through cognitive apprenticeship, and readily available computers in education settings provided a new platform for delivery of these supports (Edelson, 2001).

Video and Podcast Instruction in Chemistry Laboratory Curriculum

Chemistry departments have used video and podcast formats for support of laboratory curriculum for many years to provide modeling. Abstracts from regional and national meetings of the ACS during the last ten years include multiple presentations describing video presentations useful for preparing students to work in a laboratory (Carpenter & Wallace, 2006; Hesser & Collura, 2009; Ronkainen & Marin, 2006; Zachariah, Tatar, & Hans, 2003). Typical implementation of video- or podcast-supported curriculum includes presentations that may be
used at the beginning of a laboratory session as a pre-laboratory lecture or pre-laboratory assignments accessed on a computer that include individual viewing of a video or podcast that explains a laboratory concept, procedure or technique (Brouwer & McDonnell, 2009). An online search for “chemistry laboratory video” will retrieve hundreds of links to sites that contain resources of varying quality. Several well-funded projects have produced high quality resources that can be downloaded free of charge to personal computers and/or iPods®. An example is the video series on a Northwestern University site entitled DVAction (Hunsberger, Dougherty, Wilson, Jones, & Klausmeyer, 2010). ChemPages is a series of laboratory videos available through the Journal of Chemical Education that cover common introductory procedures and is one example of a commercially available resource (March, Moore, & Jacobsen, 2000). Video footage of chemical demonstrations and laboratory instruction are ubiquitous on YouTube. This literature review will not attempt to provide a list of available chemistry laboratory video and podcast resources, but focuses on recent publications related to the utilization of video and podcast resources as a support for modeling, coaching and/or scaffolding in undergraduate chemistry laboratory curriculum.

There are several ambitious pre-laboratory online training programs reported in the literature that employ video presentations with other supports such as brief assessments taken by the student after viewing. McKelvy (2000) describes an introductory chemistry laboratory program prepared for students and teaching assistants at Georgia Tech University. The program consists of 43 videos covering weekly laboratory procedures and techniques. Students were required to watch the videos before coming to their assigned laboratory session and complete a quiz covering information presented in the video. Teaching assistants were provided access to
the videos but were not required to view them. No quantitative data were collected on the
effects of the program, but MeKelvy reports that teaching assistants felt the videos were
helpful for their preparation. The pre-laboratory video assignment completed outside of class
was used as a replacement for the traditional pre-laboratory lecture, allowing more class time
for the experiment to be performed (McKelvy, 2000).

A software program called the Dynamic Laboratory Manual (DLM) has been used for
preparing students for chemistry laboratories at the University of Bristol and the university
developers are marketing the program in conjunction with Learning Science, Ltd. (Adams, 2009;
LabSkills, 2010). Outreach programs using the DLM resources are also being developed for
training secondary chemistry students and secondary science teachers. The outreach program
contains 12 units that include videos and simulations, safety information and assessments.
Preliminary data collected for a small number of secondary students using the software show
significant gains in scores on post-laboratory quizzes compared to students who did not have
access to the DLM software before the laboratory activity. Positive attitudes toward the DLM
pre-laboratory format were also reported (Harrison, Shallcross, Heslop, Eastman, & Baldwin,
2009).

Faculty members working in the Department of Chemistry at the University of Bath have
developed an online pre-laboratory preparation program or virtual learning environment (VLE)
for their first-term introductory course that includes four steps (Mercer-Chalmers, Goodfellow,
& Price, 2004):

1. A video describing the chemical context of the experiment to be performed

2. A video to explain background knowledge
3. A video that models techniques and procedures

4. A quiz covering all of the presentations

Students work through the appropriate module before attending the laboratory session.

Networked computers in the laboratories also allow students to access the program while performing the experiment, if they need additional assistance. Feedback from students and teaching assistants working in the laboratories has been positive. Teaching assistants reported that students using the VLE system asked higher-level questions than students in laboratories taught during previous years that did not have VLE access (Mercer-Chalmers et al., 2004).

Most video or podcast resources for the laboratory are designed for use before or after the laboratory session (Gardner & Gajewski, 2009; Heiserman, Dixon, & Bueno, 2007; Hesser & Collura, 2009; O’Brien & Cameron, 2008; Ronkainen & Marin, 2006). The recent advent of handheld devices such as iPhones® or iPods® provides a new opportunity; these mobile devices can deliver podcast instruction that is easily accessible before, during or after a laboratory session (Drahl, 2010). Abstracts from a 2009 ACS meeting include two presentations by researchers Anderson and Yocom who reported the development and use of video podcast descriptions of organic procedures for teaching laboratories during the laboratory sessions. A class set of iPods® was purchased and the Internet functions were disabled to limit their use to delivery of podcasts (Anderson & Yocom, 2009; Drahl, 2010; Yocom & Anderson, 2009). Mobile devices are becoming more common so it is logical to explore their usefulness as a teaching platform for the chemistry laboratory. Research on the effects of using podcast resources as a modeling, coaching and scaffolding tool during chemistry laboratory sessions will be important as educators consider laboratory curricula incorporating mobile devices.
Mobile Learning on Handheld Devices

Mobile learning or m-learning is an emerging technology. By definition a mobile device is any easily portable device such as a handheld or laptop computer, an MP3 player or a smartphone. MP3 players and smartphones have the advantage of being very small and thus very portable. The smartphone offers the greatest native data acquisition flexibility of any of the devices since it allows data access through both wireless networks and mobile phone networks. Mobile devices are currently being utilized in university settings in a variety of ways to deliver course information and connect students in student-centered learning projects (Johnson, Levine, Smith, & Stone, 2010). Educational institutions are developing frameworks for effective m-learning utilization (Cobcroft, 2006).

Applications of handheld mobile devices in education settings vary widely. The University of Cincinnati has linked text messaging and course management systems so that students can be notified when a new item appears on their course site (Briggs, 2007). A clicker application allows iPhones® and iPod touches® to be used as classroom response tools (Young, 2008). Programs for handheld devices have been developed that allow students to complete assessments and that provide a portal for numeric and verbal data collection (Wentzel, van Lammeren, Molendijk, De Bruin, & Wagtendonk, 2005). Use of the devices as still and video cameras can enhance student projects and flashcard applications can be used to make an always-available study set (Boychuk, 2010). Probably the most prevalent usage of handheld mobile devices for academic purposes is simple content delivery in the form of documents or audio and video podcasts and social interaction between students or students and instructors working on academic tasks.
The Horizon Report is a document produced annually by EDUCASE and the New Media Consortium that is widely regarded as the most important educational technology report in higher education. These two organizations have memberships that include over 2,000 colleges, universities and education groups. The report is a review of best practices and exemplary work assembled by an advisory board with members from ten countries. Each report identifies six emerging technologies that will have great impact on higher education during the next year, the next two to three years, or the next four to five years. The 2010 Horizon Report lists “mobile computing” as technology that is likely to have broad impact on higher education in the next 12 months (Johnson et al., 2010). It is particularly noted that the mobile market now includes over 4 million worldwide users and that smartphones are gaining popularity as an inexpensive, highly portable computing option. A section on “Relevance for teaching, learning, or creative inquiry” lists representative mobile computing applications including two related to teaching chemistry laboratories: (1) outdoor fieldwork replacing traditional expository laboratories at Bluegrass Community and Technical College that employs tablet PCs for collection and analysis of data and (2) the pilot project for this dissertation work (Johnson et al., 2010).

A mobile learning revolution is occurring (Corbell & Valdes-Corbell, 2007; Livingston, 2009). Traditional students are arriving on campuses with more laptop computers and Internet-capable handheld devices. Distance learning utilizing mobile technology is gaining visibility. The EDUCASE Key Findings report for 2009 detailed survey results focused on student ownership and use of Internet-capable handheld devices and found that 51.2% of surveyed students owned a device. An additional 11.8% indicated that they planned to purchase one in the near
future (Smith, Salaway, & Caruso, 2009). With eminent saturation of student-owned handheld devices on the horizon, curricula that depend on mobile platforms become more viable.

Summary

Handheld mobile learning platforms like the iPhone® and iPod touch® are inexpensive, pocket-sized and offer increasing computing power. As these tools become more common on university campuses and among distance learning students, applications for their integration into the teaching environment are multiplying. Technology-based tools must be part of a coherent pedagogical approach if they are to be effective and educators must consider the ways students learn in the design of technology-supported curriculum (Bransford et al., 2000).

Cognitive apprenticeship theory can be used to describe the training of students in laboratory skills and concepts (Elliott, 2006; Lagowski & Stewart, 2003). This theory compares academic training to a traditional trade apprenticeship and identifies six methods that are central to teaching and learning (Collins et al., 1991; Collins et al., 1989). The first three methods are modeling, coaching and scaffolding and assume frequent interaction between the instructor and student (Edmondson, 2005). In teaching laboratories, the personal attention given to a student can be limited by a relatively high student to instructor ratio. Technology can fill the gap by providing a platform for expert modeling (Collins, 1991).

Traditionally, the instructor for a laboratory course delivers a pre-laboratory lecture that models important physical and cognitive tasks pertinent to the experiment that students will perform. Many curricula include a pre-laboratory assignment to further prepare students. Some universities use video clips and full video lectures incorporated in to pre-laboratory assignments as a substitution or supplement to the pre-laboratory lecture (Adams, 2009; McKelvy, 2000;
Mercer-Chalmers et al., 2004). This type of video lecture format can provide standardized instruction that may be particularly important when there are multiple sections taught by many different teaching assistants. While the pre-laboratory video instruction can be very helpful, videos are generally not available during the laboratory session for student reference.

A mobile learning platform such as the iPhone® or iPod touch® allows the student to access podcasts on pertinent chemistry laboratory topics as needed during the laboratory session. Therefore it can more adequately fulfill the roles of modeling before task performance and coaching with scaffolding as the student begins working in the laboratory. An instructor is still available as an assistant, but the mobile learning platform may allow student to work more independently and free the instructor to pursue higher-level interactions.

Mobile learning devices are becoming much more common (Smith et al., 2009). Research on the use of this new technology in education settings that provides a thorough description of the learning environment will provide essential information for educators wishing to harness the potential of the new technology in an effective manner.
CHAPTER III

METHODOLOGY

Introduction

The topic of this study is the effectiveness of podcasts delivered on-demand as a scaffolding tool during general chemistry laboratories taught with an inquiry-based curriculum. The specific mode of delivery of the podcasts was an iPhone® or iPod touch®. The research was conducted at Abilene Christian University (ACU), a small, private, co-ed university located in the mid-western part of the state of Texas. This chapter describes the population that was studied, the course curriculum and the design of the study. The development of the assessment procedures and their reliability are also included herein.

Research Questions

Research Question 1: When relevant chemistry podcasts are available for on-demand access during a general chemistry laboratory taught with an inquiry-based curriculum, how frequently will student research teams access them?

Research Question 2: What differences are evident in the number, types, and topics of scaffolding interactions between student research teams and instructors in laboratory sections that have access to on-demand podcasts but no pre-laboratory lecture and those who have been instructed using a traditional pre-laboratory lecture?

Research Question 3: What do the student outcome measures of laboratory report grade average, laboratory quiz average, laboratory final exam grade and laboratory course average indicate about performance differences between students who have access to the on-
demand podcasts versus students who have received the same information in a traditional lecture format?

Methodology Overview

Though the types of experiments and topics covered in a general chemistry laboratory course may vary from program to program, all share the common goals of introducing students to foundational chemistry techniques and procedures and helping students connect chemistry content with phenomenon in the physical world. An important secondary goal is to help students develop inductive and deductive reasoning skills in the context of chemistry experiments.

The schedule for the first-semester general chemistry laboratory program used in this study consisted of 12 weekly laboratory sessions and a comprehensive exam given during the final laboratory meeting. This curriculum is typical of general chemistry programs at many universities. During the first weeks of any course, students adjust to the academic structure and physical environment of the course. Taking this acclimation period into consideration, data on scaffolding interactions were not collected during the first two laboratory sessions. The curriculum will be described in detail below.

Demographic data and entrance exam scores were collected from a university database for use establishing the homogeneity of students in the treatment groups. For this study, the first treatment group was comprised of students in four sections of general chemistry laboratory who were given on-demand podcast access. The second treatment group was comprised of students in two analogous general chemistry laboratory sections who received a traditional pre-laboratory lecture and were not given podcast access. Each section was led by
the same instructor using the same inquiry-based curriculum and met from 1:00-4:50 PM or
1:30-5:20 PM on a Tuesday, Wednesday or Thursday afternoon. Each afternoon two sections
ran concurrently and the sections met together in the same lecture room for introductory
activities and then divided into two laboratory rooms with separate teaching assistants to
conduct experiments. Podcasts were prepared for seven of the ten laboratory sessions. During
weeks when no podcasts were available for any of the sections, each section received a pre-
laboratory lecture. This research design allowed comparison of data during weeks when all
sections received a lecture with data for weeks when some sections used podcasts to provide
additional evidence of the effects of podcast usage.

Research Question 1 was investigated using data collected for seven laboratory
sessions; these were the sessions during the scaffolding data collection window for which
pertinent podcasts were available. The prepared podcasts were loaded on a secure file
management system at ACU that allowed the students to stream the podcasts but did not allow
download to the handheld devices. The management system allowed restriction of access to
students in particular lab sections during selected time constraints. This assured no cross-
contamination of the treatment groups since students enrolled in the lecture treatment
sections were not able to access the podcasts through their login accounts and students
enrolled in the podcast treatment sections only had podcast access through their login accounts
during their assigned laboratory period. A daily file usage log was available upon request. The
file usage log listed each time a podcast was accessed by time and by name of individual logging
in to the system. An accurate count of the number of times a particular podcast was accessed
by an enrolled student during each laboratory session was obtained from these data.
Research Question 2 was investigated by collection of data on the numbers, types, and topics of interactions between the instructors and student research teams during each of the ten laboratory sessions. In a laboratory taught in a traditional format, an instructor presents a pre-laboratory lecture that includes essential information about use of equipment, experimental procedures, safety measures, and instruction on special calculations or data processing techniques. This material is often very dense and students may struggle with understanding and remembering all of the important details. Instructors provide scaffolding during the laboratory session to assist students as they apply the information and techniques discussed in the pre-lab lecture. It is proposed that if podcasts are an effective scaffolding support when used in the laboratory setting, the result should be a reduction in the number of times instructors interact with student teams in a scaffolding capacity.

For this study instructors were trained to recognize scaffolding interactions and count and categorize them. The category types were adapted from a recent publication standardizing evaluation of inquiry-based instruction (Brandon, Taum, Young, & Pottenger, 2008). During the full 4-hour laboratory period in each of the six sections for the ten weeks included in this study, the instructors recorded each scaffolding interaction and parsed the interactions according to a classification system based on a simplification of categories from the “Inquiry Science Observation Coding Sheet” (Brandon et al., 2008).

A scaffolding interaction, as defined for this study, was an interaction centered on the topic of the week’s experiment that may have been initiated by the student team spokesperson or by the instructor. It was more than a simple one-question exchange in which the team or instructor was gathering basic information; it was an interactive discussion of a concept or
procedure. Each scaffolding interaction was classified by type as either a clarifying interaction or a follow-up interaction.

A clarifying interaction as defined for this study was an interaction through which an instructor provided assistance to help the team accomplish their experimental goals and encourage them to successfully complete their activity. It was focused on the task at hand. It encompassed interactions about concepts as well as how to carry out a procedure or technique and how to use formulas or correctly complete calculations. Students struggling with the activity might have initiated a clarifying interaction and an instructor would often initiate a clarifying interaction when they observed an ineffective procedure, detrimental performance of a laboratory technique or improper processing of data or when they assisted a team during a discussion of a concept central to the planning and execution of a valid experiment.

A follow-up interaction as defined for this study was an interaction through which an instructor attempted to guide the student team to a new level of understanding connecting with ideas from previous experiments or related concepts. This type of interaction may have been initiated by students who wished to discuss their thought processes or initiated by an instructor as they saw opportunities to challenge student ideas and help them develop a broader understanding of a concept or physical phenomenon.

After determining whether the interaction was a clarifying or follow-up interaction, the instructor recorded the topic of the interaction as either Q, E or P. Q interactions occurred while the students were working through an inquiry worksheet activity in preparation for planning and executing their experiment and were assigned subtopic identifiers of 1 or 2. Those that were coded E occurred during the execution of the experiment and had subtopic codes 3 –
6. Codes in the P category denoted interactions that occurred during data processing or writing of team lab reports and had either 7 or 8 subtopic identifiers. The overall topic and subtopic coding list for both types of interactions was as follows:

- **Q1**—numerical issue during inquiry activity
- **Q2**—ideological issue during inquiry activity
- **E3**—tools/equipment during experiment
- **E4**—investigative procedure during experiment
- **E5**—data (quantitative or qualitative) during experiment
- **E6**—safety during experiment
- **P7**—claims and evidences during processing of data
- **P8**—student’s prior knowledge or experiences during processing of data

Each instructor carried a small card in their lab coat pocket with a summary of the categorization rubric and a grid for data entry. At the conclusion of a scaffolding interaction, the type and topic of the interaction were immediately recorded. To assure reliability of the data, the instructors participated in training in the use of the categorization system before the beginning of the semester. In addition, during the first two weeks of the laboratory course, I spent two hours during a lab period with each TA listening to each interaction in which they participated. The TA and I separately identified and categorized the interactions and then discussed the coding decisions. This process helped with standardization of the categorization process in the “live” classroom. The collected data on the interactions for laboratory sections using podcasts and those not using podcasts allowed a comparison of the differences in
number, types and topics of scaffolding interactions. The reliability of the data collection for scaffolding interactions will be discussed in the Tools section of this chapter.

Research Question 3 was investigated by collection of data on student outcome measures for each laboratory section. The laboratory course grade was computed by taking the weighted average of the mean team report and reflection grade (60%), the mean quiz grade (20%), and the laboratory final exam grade (20%). The final exam and quizzes were objective tests and were graded by the TAs using a detailed key provided by me in my role as the faculty instructor. The quizzes were weighted equally when computing the mean value. The team lab reports and student reflections were graded according to a rubric. Within the team lab reports and reflections category, the reports accounted for two-thirds of the mean grade and the reflections accounted for the remaining one-third. Appendix B includes copies of the syllabus, quizzes, final exam and grading rubrics for the reports and reflections. A sample student lab report and reflection are also included.

The TAs were trained in the use of the grading rubrics and coached as they graded the reports and reflections for the first several weeks. During the second week of the course the students were also trained to evaluate reports and reflections using the rubric in an effort to help them understand the course expectations. Grades on the student-generated reports and reflections improved drastically after the student training. Inter-rater reliability (IRR) studies were performed on a sample of the graded reports and reflections to establish the consistency of grading across the laboratory sections.
Study Sample

It was necessary to select a course with an inquiry-based curriculum that was well established and a population that would have uniform access to portable devices for podcast delivery. The student population selected for this study was all students enrolled in General Chemistry I laboratory at Abilene Christian University (ACU) during the fall 2009 semester. ACU is a small private university located in Abilene, Texas with an undergraduate population of approximately 4500 students. The student body is diverse with students from 30 foreign countries, 49 of the 50 United States of America and various educational and socio-economic backgrounds. The students enrolled in General Chemistry I during the fall 2009 semester reflected the demographics of the university. Students were required to take a mathematics placement test and place into Pre-Calculus II or a higher mathematics course before enrollment in chemistry; this prerequisite limited enrollment to students who should have been academically prepared for the coursework. Typical attrition rates for General Chemistry I lecture and lab are 8-14%. Though the two courses were graded separately, the catalog requires concurrent enrollment in the lecture and laboratory sections. Students were not permitted to drop one course without dropping the other.

Outcome data for 133 students who completed the laboratory course and were enrolled in one of the six laboratory sections were included in this study. There were 150 enrolled students at the beginning of the semester and 17 dropped the course for an attrition rate of 11.3%. Twelve of the seventeen students who dropped the course did so within the first two weeks of the semester before data collection on scaffolding interactions had begun. These “early drops” are generally due to scheduling conflicts, not academic difficulties. The attrition
rate calculated by considering the enrollment at the two-week mark and the five students who dropped the course after that time was 3.6%. During the first laboratory meeting for each section, the planned study was described to the students and a written consent form was provided. A copy is included in Appendix A. The students were asked to read and complete the consent form; each of the students who completed the course agreed to participate in this study. Data for one student who agreed to participate was omitted because of incomplete grade records, so that data for 132 of the 133 students who completed the course were analyzed for this study.

During the fall 2008 semester ACU began the deployment of iPhones® or iPod touches® to all entering freshman students. The purpose of the deployment was to encourage use of the devices in academics. The portable devices were deployed again during the fall 2009 semester to all entering freshmen. Since the population of students enrolled in General Chemistry I was predominantly students who were freshman and sophomores, there was adequate device coverage in each laboratory section; each research team of 3-4 students had at least two devices available for use during every laboratory session.

All students were concurrently enrolled in General Chemistry I lecture and General Chemistry I laboratory. The chemistry courses were designed to meet the curriculum requirements for science majors and students completing pre-requisites for health professions programs. All regular sections of the general chemistry lecture course were on a coordinated schedule; though taught by three different instructors each section covered the same materials at a closely aligned pace and all sections gave identical exams on the same dates. There was a single honors section of General Chemistry I lecture with 20 enrolled students. The honors
section covered the same materials as the regular sections and included an extra chapter on molecular orbital theory near the end of the semester. Each lecture section was taught in a traditional lecture style format using the same textbook and online homework system.

All students self selected class schedules. There were six available laboratory sections with an enrollment limit of 28 students each. Every laboratory section was listed on the schedule under the name of the same instructor and an afternoon time slot on either Tuesday, Wednesday, or Thursday afternoon. None of the advisors, students, or faculty members knew which sections would have access to podcasts. For the purpose of this study, the two labs meeting on Tuesday and two labs meeting on Thursday were chosen to use podcasts and the two labs meeting on Wednesday were chosen to receive the same information contained in the podcasts in a traditional pre-lab lecture format.

The inquiry-based curriculum used to teach the laboratory course is described in the Academics section of this chapter.

Instructors

Faculty Instructor

In addition to being the investigator for this study, I am the faculty instructor who taught the six laboratory sections used as the study sample. I have seventeen years teaching experience and have taught general chemistry laboratories at ACU for the past ten years. For the past eight years I have coordinated the general chemistry laboratory curriculum at ACU and have adapted the materials used for teaching the laboratory from standard general chemistry experiments to closely align with the ACU’s general chemistry lecture curriculum.
Teaching Assistants

Undergraduate teaching assistants (TAs) were hired and trained to help with each laboratory section. The teaching assistants were sophomore or junior students who had completed General Chemistry I and II lecture and laboratory with a grade of B or higher and were recommended by faculty members. Before the first lab meeting the TAs participated in three hours of training in facilitating inquiry based labs, identifying types of interactions with student groups according to a coding rubric, and grading laboratory reports using a grading rubric. Each week during the semester I met with the TAs in my role as faculty instructor to prepare for the following week’s laboratory session.

TA responsibilities included circulating among the research teams during the laboratory session and asking questions to help direct student research teams, answering questions from student research teams, assisting with minimal set-up and clean-up duties and grading lab reports, student reflection papers and weekly quizzes. As the faculty instructor, I was present during all laboratory sessions as a supervisor and continued training the TAs and modeling effective instruction techniques during the laboratory sessions.

Environment

Physical Environment

This course was taught in three rooms: a lecture room that accommodated 56 students, and two laboratory rooms that accommodated 28 students each. At the beginning of each laboratory session students assigned to two sections met in the lecture room. The desks in the lecture room were arranged in fourteen groups of four. During the first hour of the laboratory period, students sat in assigned groups or teams and completed a guided inquiry activity
intended to prepare the students for the experiment. The instructors were available to assist
the teams as they worked. When the guided-inquiry activity had been completed by all of the
student teams, the spokesperson for each student team briefly presented their planned
experiment. After minimal class discussion, as faculty instructor, I made comments about
laboratory safety or arrangement of supplies in the laboratory rooms. If podcasts were not
available for student use, I presented a succinct pre-laboratory lecture.

Next, the students moved into the laboratories to conduct their experiments each week.
The two laboratory rooms were located across the hall from one another. Student teams were
assigned to fully equipped lab stations. Each section had a TA and I moved between the two
sections to help as needed. The time spent in the laboratory varied from week to week but was
usually about one and one-half hours. When the student teams had completed their
experiments, they returned to the lecture room to write up the group portion of the laboratory
report. Laptop computers were provided for use in completing the reports and all reports were
electronically submitted before the student teams left the laboratory session. The data
processing/report writing phase generally took about an hour. As each team submitted their
report, individual students were given a post-lab quiz. Students were free to leave when they
had completed the quiz.

Each laboratory section met for 14 sessions during the semester. One class meeting was
used for a comprehensive final exam and one meeting was designated a “make-up” lab session
for students who had missed a laboratory earlier in the semester.
Academic Environment

The material for the laboratory course was presented in a guided inquiry format, and has been developed and refined over the past five years. Three ACU chemistry professors with a total of 60 years of general chemistry teaching experience have had extensive input in editing and improving the pre-laboratory activities, guided inquiry activities and laboratory procedures. The laboratory curriculum was closely coordinated with the lecture curriculum. Laboratory activities and experiments generally introduced new topics that would be covered in lecture during the following week. First semester general chemistry topics were often familiar to students, so some anticipated the experimental results. In an effort to encourage all students to consider the material with a fresh perspective, the laboratories were planned to cause students to question what they may have believed they already knew. (An example was the laboratory for Week 2: How can I know what compound is formed?) The topics covered were aligned with the lecture course textbook Chemistry, 9th edition by Whitten, Davis, Peck, and Stanley (Whitten, Davis, Stanley, & Peck, 2010). The General Chemistry I lecture course covered chapters 1-12 in this textbook. Appendix Table B.1 lists the experiment titles and topics introduced for each week of the fall 2009 semester along with the corresponding chapter and chapter title in Chemistry, 9th edition. Chapter 12 was covered out of sequence after chapters 1 and 2 and no laboratory session was planned to introduce chapter 9 (molecular orbital theory), since this chapter was only covered in the honor’s section.

Within each laboratory section students were assigned to research teams of 3-4 members. The faculty instructor made the team assignments using results of the Group Assessment of Logical Thinking (GALT) test given to all enrolled students on the first day of
class. The GALT test is reported to classify students according to the Piagetian categories of mental development and has been shown to have a correlation with performance in general chemistry courses (Bunce & Hutchinson, 1993; Roadrangka, 1986). A GALT score of 0-5 corresponds to the concrete operational stage, a score of 6-7 corresponds to the transition between concrete and abstract stages and a score of 8-12 corresponds to the abstract operational stage (Roadrangka, 1986). Only five students spread throughout the six lab sections scored in the 0-5 range. To form balanced groups, each group was assigned a student with a high GALT score (above 10), a student with a low GALT score (below 8) and then one or two students with a mid-range GALT score (8, 9, or 10). Working roles within each group were assigned on a rotating basis to assure that all students participated as equivalently as possible. Appendix Table B.2 lists each group role along with a description of the associated job responsibilities. There were four team roles: manager, Technician 1, Technician 2, and spokesperson. When a team had only three members, the responsibilities of Technician 2 were divided among the other team members.

Written materials for the weekly laboratory sessions were posted on a class site in a file management system at ACU. A separate folder for each week contained pre-laboratory problem sessions (required for Weeks 7, 9, and 12), the laboratory procedure and appropriate material safety data sheet (MSDS) pages that could be viewed on a computer, iPhone® or iPod touch®. Podcasts were also posted in the folder and only released for viewing during the laboratory session to prevent cross-contamination of treatment groups. Before coming to class, students were required to read the laboratory procedure and view the safety information and then write a brief summary of the procedure in their lab notebooks. Since the curriculum was
intended to allow the students to plan portions of the procedure and investigate their own questions, the procedures provided were very basic, giving only essential detail. TAs checked student lab notebooks at the beginning of class for completion of the pre-laboratory assignments.

As an introduction to each laboratory session, the student teams worked independently through an inquiry-based worksheet. This document was not posted with the other written materials but was passed out at the beginning of lab each week. The purpose of the inquiry-based worksheet was to help students begin to think about concepts that were important for understanding the topic of the week’s experiment and ensure that they had the background information needed to plan a meaningful experiment. The worksheet was not submitted for grading.

At the end of the inquiry worksheet, a prompt directed the student research teams to plan their experiment for the week based on the procedure they had already summarized and the “big question” they had proposed as part of their pre-laboratory assignment. The team members worked together to come to a consensus about what question they would investigate as a team and make decisions about how the procedure would be used, what data would be collected and how the data would be processed. The amount of student-initiated planning or level of inquiry varied from week to week. Each spokesperson gave a report to the class on their team’s planned experiment. This allowed the instructors to have an overview of the work students were planning to perform and also allowed all of the teams to hear their classmates’ plans. Hearing other experiment plans spurred them to think about their planned experiment from a different perspective and student teams often modified their planned experiments after
the class reports. During some weeks the instructors facilitated the coordination of experiments so that data from all teams could be pooled at the end of the laboratory session to give students a broader perspective. The inquiry laboratories in this curriculum were modeled on the science writing heuristic format (Poock et al., 2007).

The description “inquiry-based” has been used to identify activities and experiments that engage students in observing a written or physical model, asking questions and collecting and analyzing data to form a hypothesis. In an inquiry-based laboratory, the amount of student-initiated work may vary depending on the complexity of the ideas and laboratory techniques being introduced. In the curriculum for the course used for this study, some experiments were almost completely student-generated. Some weeks, detailed procedures were provided for part but not all of the experiment, so that students still generated a significant portion of their planned work. There were a few weeks when students worked through an inquiry-based worksheet but the amount of independently generated experimentation was minimum due to the topics being covered. A method of identifying level of inquiry is important when describing a laboratory curriculum.

Fay and coworkers (2007) recognized the lack of consensus in identifying “inquiry-based” laboratories and have published “A rubric to characterize inquiry in the undergraduate chemistry laboratory”. Using their rubric, the laboratory experiments used in this study were evaluated for level or extent of inquiry according to a four-point scale. An inquiry level of 0 corresponded to an expository style experiment for which the problem, procedure and data analysis techniques were provided. An inquiry level of 1 corresponded to an experiment for which the problem and procedure were provided and students were responsible for
independent data interpretation. If students were provided the problem to investigate, but
developed their own procedure then analyzed and interpreted the data, the experiment was
assigned an inquiry level of 2. An inquiry level of 3 corresponded to a very open-ended activity
that required students to identify a problem to investigate, then plan an experiment, collect
data, analyze and interpret the data (Fay et al., 2007).

Table 1 lists each of the laboratory experiments in the Fall 2009 ACU General Chemistry
I laboratory curriculum with its level of inquiry determined using the published rubric. Three
chemistry professors with many years of general chemistry teaching experience evaluated the
level of inquiry for each experiment. They independently examined the experiments and then
met to discuss the ratings and determined a consensus inquiry score as judged by this rubric.
Experiments conducted during Weeks 9, 10, and 11 were listed as having inquiry levels of 0/2.
The 0 score reflected the fact that the titration procedure and two synthesis procedures were
not student generated and thus involved no inquiry. The 2 score was an evaluation of the
second part of each of these experiments for which students did generate their own
procedures. After synthesizing alum they planned an experiment to test the efficacy of the
alum as a flocculent and after synthesizing soap they tested the soap as an emulsifier. During
the week when they learned how to perform a titration, they planned an experiment to test
commercial antacids and determined the concentration of acid in samples that had been
treated with an antacid. The activity during Week 12 required students to use model kits to
determine electronic and molecular geometry; this dry experiment is traditionally included in
general chemistry laboratories. The students were given the kits with a description of how to
use them and were asked to work on a series of structures to classify them according to shape.
It was difficult to classify according to the rubric since students were not verifying their proposed structures with any given data, but the hope was that they would take what they had learned and use it to verify structures that were covered in lecture at a later date. An inquiry level of 1 was assigned to this experiment.

Table 1

<table>
<thead>
<tr>
<th>Week</th>
<th>Experiment title</th>
<th>Inquiry level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How “reliable” are the volume markings on beakers and graduated cylinders?</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>How can I know what compound is formed?</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>How can we compare changes in pressure, volume, and temperature for a trapped gas sample?</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Determining R. Will our value match the one we’ve memorized? Will we even get a constant?</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Investigating a reaction between lead(II) nitrate and potassium iodide in aqueous solution</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Identifying elements by a flame test. FIRE!!!</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Using the Cambridge Crystallographic database to investigate atomic radii</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Can we predict which metals will react?</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Using titration to determine the neutralizing effects of antacids on HCl (stomach acid!)</td>
<td>0/2</td>
</tr>
<tr>
<td>10</td>
<td>Making an alum from scrap aluminum and testing it as a flocculent</td>
<td>0/2</td>
</tr>
<tr>
<td>11</td>
<td>Making soap and testing its ability to suspend dirt and oils in aqueous solution</td>
<td>0/2</td>
</tr>
<tr>
<td>12</td>
<td>Using model kits to predict the structures of simple compounds</td>
<td>1</td>
</tr>
</tbody>
</table>

After moving from the lecture room to the laboratory room, student research teams performed their planned experiments. Each student kept a laboratory notebook in which they
recorded quantitative and qualitative data and calculations as well as team data analysis. When all data were collected, the students moved back to the lecture room, checked out laptop computers, analyzed their data and wrote the team lab report. Most weeks the spokesperson placed a summary of team data on the whiteboard at the front of the room, so that all research teams could read and use the class data in drawing their final conclusions. As the faculty instructor, I usually conducted a brief class discussion of the data collected by all of the teams during the experiments. When the team lab report had been submitted electronically, each student took a quiz that covered the lab performed on that day. Students were permitted to use their laboratory notebooks, but not podcasts, as a resource for the quiz given at the end of the laboratory session. Quiz questions centered on the types of techniques and calculations used by all students during the lab as well as the important concepts introduced by the inquiry worksheet. Quizzes also included questions from previous week’s experiments. Students were free to leave the classroom when they had finished their lab reports and quizzes.

The last responsibility of the individual student for each laboratory session was to write a 200-350 word reflection that was submitted electronically by midnight the Sunday night after the laboratory experiment was performed. This reflection required the student to rethink what they had investigated and learned during the laboratory session.

Research Design

Introduction

Students working in an introductory chemistry laboratory enter university-level coursework with a wide variety of background preparations. Some students have had extensive laboratory experience; others have never worked in a laboratory. In order to assure that each
individual has the necessary information and skill set to successfully negotiate a general chemistry laboratory curriculum, the instructors provide academic support. Traditionally, this support includes a pre-laboratory assignment, a pre-laboratory lecture and scaffolding assistance during the laboratory session provided by either a faculty instructor or a teaching assistant. This support is even more essential when the course is taught with an inquiry-based curriculum that encourages student-initiated activity.

While teaching a laboratory, it is a common experience for instructors to repeat information presented in the pre-laboratory lecture multiple times during their interactions with students. Pre-laboratory lecture material may be too dense for students to fully comprehend or students may not be able to appropriately sort the new information until they are confronted with decisions that must be made during the actual experiment. A method of providing the pre-laboratory lecture information for students to access on-demand during the laboratory period may provide some extra support that frees the students to work more independently and frees the instructors to pursue higher level conversations. The method investigated during this study was on-demand podcasts that could be accessed on handheld devices on an as-needed basis.

Gathering information on the extent of student usage of podcasts was the focus of the first research question. Data collected on podcast usage provides some insight into whether students used the prepared podcasts and if there were trends in usage. The second research question addresses the effect that podcast usage might have on the number, type, and topics of instructor/student interactions and interpretation of collected data may contribute to an understanding of whether podcasts are effective as a scaffolding support during general
chemistry laboratories. Investigation of the third research question may provide evidence on whether student performance is affected by the presentation method.

Study Design

A nonequivalent, quasi-experimental design was used to compare the effect of on-demand podcast access with the effect of a traditional pre-laboratory lecture on scaffolding interactions between the student research teams and instructors and on student outcome measures. Quantitative and qualitative data were collected. The different modes of presentation of chemistry content were the independent variable in this study that may impact two categories of dependent variables. The first category of dependent variables was categorization data on scaffolding interactions between student research teams and the instructors. The second category of dependent variables was the student outcome measures that comprise the student course grade average. The results of this study contribute to an understanding of student use of on-demand podcasts and how the availability of the pertinent podcasts in the laboratory setting compare with the traditional pre-laboratory lecture as a support tool for student research teams.

Academic ability as measured by GALT pre-test scores and American College Testing (ACT) examination scores were used to compare the pre-lab lecture group with the on-demand podcast group to determine whether differences in these cognitive measures were evident. This comparison was an effort to control for academic variables that might skew data on the amount of scaffolding support needed by the research teams or on student outcome measures. If the groups were equally academically prepared, the expectation would be that the dependent variables would not show any significant differences when all of the laboratory
sections were taught in exactly the same manner. Likewise, if ability and environment were equivalent, it could be inferred that differences seen between the groups receiving different treatments were a result of the treatment. While it is not possible to establish equivalence, comparison of the GALT and ACT aid in establishing academic similarity.

To further establish academic similarity of the treatment groups, an interrupted time series investigation was embedded in the research design. For seven of the ten weeks of the data collection period two sections received a pre-lab lecture. During the same seven weeks four laboratory sections received instructor support through access to podcasts, and no pre-lab lecture for 6 of the 7 sessions. For one of these seven weeks, the podcast treatment group also received a pre-lab lecture covering the information in one of the podcasts that students accessed. Table 2 summarizes the treatments for each group over the ten-week window. This design allowed comparison of the dependent variables for the treatment groups when they were receiving different treatments, receiving the same treatments, and for one session when the podcast treatment group received lecture plus podcasts.

Table 2

Summary of Group Treatments During Data Collection

<table>
<thead>
<tr>
<th>Group</th>
<th>Treatment</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
<th>Week 7</th>
<th>Week 8</th>
<th>Week 9</th>
<th>Week 10</th>
<th>Week 11</th>
<th>Week 12</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Podcast” treatment</td>
<td>Podcast</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lecture</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Lecture” treatment</td>
<td>Podcast</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lecture</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

It was important to provide a baseline comparison between the treatment groups. For this study the baseline comparison was provided by examination of data for the weeks when
both treatment groups received the same treatment as in Weeks 6, 7, and 12. A within-group treatment 1/treatment 2 design would not allow valid data comparison because difficulty levels and topics of laboratory activities vary greatly across a curriculum. Values of the dependent variables for different experiment weeks would not be expected to be consistent even when the treatment sample and environment were identical. Comparison of the two treatment groups participating in the same laboratory experiment under the same treatment that shows no significant differences would support a conclusion that any differences in dependent variables when different treatments were applied were a result of the treatments. The single week when the podcast group had access to on-demand podcasts and received a lecture provides some data on the effectiveness of the two treatments when used in conjunction.

Podcasts and Pre-laboratory Lectures

Two different software programs were used to prepare the podcasts: Profcast™ and Podcast Producer™. All of the podcasts were comprised of slides prepared in PowerPoint with corresponding audio tracks. A key feature of the podcasts was their brevity. They varied in length from 2-5 minutes and were intended to provide easy and quick access to needed information so that students were more likely to use them as a reference tool. Copies of the podcast slides and text of the accompanying audio tracks are included in Appendix C. Each week the podcasts pertinent to the laboratory activities were loaded in the files management system for the podcast treatment sections a few minutes before the beginning of the class session and removed at the conclusion of the class session.

Topics for the podcasts were selected based on discussions with faculty instructors experienced in teaching with the course curriculum. They paralleled the materials usually
presented in the form of a pre-lab lecture. The faculty instructors identified common student misconceptions and common procedural difficulties as observed through multiple years of teaching experience that were conducive to presentation in the podcast format. The podcasts can be classified according to the types of information they provided. Podcasts of the first type described in detail mathematical information essential in chemistry calculations or concepts central to planning an experiment. This category included podcasts entitled “Determining Significant Figures,” “Simple Statistics,” “Planning an Experiment,” and “Comparing Reactivity of Metals.” Those of the second type described general lab procedures used throughout the semester. The podcasts in this category were “Mass Determination,” “Reading Liquid Levels,” “Using Pipets,” “Using Acids Safely,” “Filtering,” “Collecting a Gas Sample,” “Using a Crucible,” “Vernier® Gas Pressure Equipment” and “Titration Techniques.”

A podcast review team was assembled that included faculty instructors, TAs, and past students. Included as part of team were two students who had been top performers in the honor’s chemistry section, two who had been B/C students in regular chemistry sections, and two students who had failed chemistry, in addition to three students who had taken chemistry at other universities. They were asked to review and critique the podcasts for clarity and completeness. Based on their input, podcasts were modified before being deployed.

In my role as faculty instructor, I carefully presented the podcast information in a pre-lab lecture format for the treatment group that did not have access to podcasts. The pre-lab lecture was delivered in the laboratory lecture room for all students enrolled in two concurrent laboratory sections. The lecture was typically 10-15 minutes in duration and material was covered at a slower pace than it was in the podcasts; students can rewind or pause a podcast,
but a live instructor must allow students time to process information as it is presented. I prepared the podcasts and delivered the lectures for each of the six laboratory sections during this study.

Pilot Project

In preparation for this study, a pilot project was conducted during the fall 2008 semester. The population chosen for the pilot project were students in General Chemistry I laboratory at ACU. The iPhone®/iPod® deployment program was new and only freshmen students had been issued devices. To guarantee adequate device coverage, one section of General Chemistry I laboratory was selected to use podcasts and enrollment was restricted to freshman students. Students, advisors and faculty were not aware of the planned podcast usage during the student registration period. Podcasts were prepared and the laboratory curriculum was planned and executed using the same methods as described for the study project. The single freshman-only section used on-demand podcasts and the remaining four sections received traditional pre-lab lectures.

Through work done during the pilot project, the method of categorizing scaffolding interactions was refined and its reliability established. Grading rubrics for the team lab reports and reflection sections were also improved and extensively tested for reliability. Quizzes were written to accompany every laboratory session and administered during the pilot project. Each week I discussed student errors on the quizzes with the TAs who had graded them and occasional adjustments were made to improve clarity of expression in the written quiz questions. The improved quizzes were used during this doctoral research project. The final exam given during the pilot project and dissertation study has been used in nearly analogous
forms for four years in teaching this curriculum and has been evaluated by three experienced general chemistry professors for content and clarity.

During weekly meetings with the laboratory instructors the common student difficulties experienced during the previous week’s experiment were discussed. On the basis of these conversations and some student feedback, several podcasts were revised to improve content or clarity. Working with the 2008 TAs and faculty instructors was crucial in the development of improved methods for training the fall 2009 TAs to assure strong inter-rater reliability in data collection and TA confidence in facilitating inquiry-based laboratories. Minor changes were made in the laboratory curriculum before the fall 2009 semester due to rearrangement of topics in a new edition of the general chemistry lecture book used in the accompanying course.

Tools

*Group Assessment of Logical Thinking Test*

The GALT test is a 12-item tool constructed for characterizing student logic ability and was given to all enrolled students on the first meeting date of the General Chemistry I laboratory sessions (Roadrangka, Yeany, & Padilla, 1983). A study published by Bunce and Hutchison shows the correlation between student GALT scores and performance in chemistry courses to be equivalent to or greater than the correlation between the mathematics SAT score and chemistry performance in introductory chemistry courses for non-science majors and nursing majors. The same study shows correlation between the GALT score and performance for students enrolled in chemistry courses for science majors, but a stronger correlation between mathematics SAT score and chemistry performance for science majors (Bunce & Hutchinson, 1993).
A major advantage of the GALT test over entrance exam scores such as the ACT or SAT as a cognitive measure for comparing the treatment groups is that it is quickly and easily administered to the sample population at the time of entrance into the chemistry course. For this research, the GALT was used as a tool for comparing student logical thinking ability at the start of the course and as a tool for dividing students into balanced research teams within laboratory sections.

ACT Test

The ACT and SAT standardized tests are used by institutions of higher learning as a measure of a student’s academic ability. As a tool for predicting student performance, many studies have shown a correlation between performance on these standardized tests and achievement in college-level coursework (Bunce & Hutchinson, 1993; Rothstein, 2004; Sackett, Kuncel, Arneson, Cooper, & Waters, 2007; Schmitt et al., 2009). The majority of students comprising 71.7% in the sample population for this study had taken the ACT before enrollment in the chemistry laboratory course. The remaining 28.3% had not taken the ACT, but had taken the SAT test. Concordance tables published on the ACT and College Board Websites provide scaled scores for conversion of composite SAT scores to estimated composite ACT scores ("ACT-SAT Concordance," 2010). For the purpose of the comparison of treatment groups in this study, students in our sample who did not have ACT scores were assigned an estimated ACT score using the published concordance.

While the ACT test may be a more comprehensive measure of students’ academic ability than the GALT test, ACT scores obtained from the university database may have been from test administrations anytime within the past ten years and may not reflect a current measure. The
ACT scores were used as a tool for comparison of the mean student academic preparation in the two treatment groups.

The correlation between GALT pre-test scores and composite ACT scores with the laboratory final exam grade and with the laboratory course grade indicated their strength as a predictor of academic performance in the General Chemistry I laboratory course for the sample population.

*Scaffolding Interaction Categorization Scheme (SICS)*

The Scaffolding Interaction Categorization Scheme (SICS) was developed for this study through an adaptation of categories from the Inquiry Science Observation Coding Sheet (ISOCS) (Brandon et al., 2008). There is a dearth of tools available for the collection and coding of student or instructor behavioral data during inquiry-based science instruction. Most research on the effects of inquiry-based learning at the secondary and post-secondary levels has focused on student outcome measures rather than targeting observational data. For this study, the specific goal was accurate counting and categorizing the number of scaffolding interactions during each laboratory period. Scaffolding interactions, as defined for this study, are the centerpiece of student support.

Brandon et al. (2008) developed the ISOCS for the assessment of adherence to an inquiry-based curriculum in middle school science classrooms. The ISOCS is a tool that focuses on student-teacher interactions. In their publication describing the development of the ISOCS, the authors give a very thorough description of the process of narrowing the focus of the assessment. They conclude that “student-teacher interactions are the heart of the interchange
that is initiated by teacher questions: they reflect the primary content that the instrument is intended to address” (Brandon et al., 2008, p. 254).

The strong validity and extensive reliability data as well as thorough description of training observers and challenges in the process of development of the ISOCS provided excellent background for adapting aspects of the tool for use in the present study. During its development, the ISOCS was used in assessing inquiry science in videotaped class sessions. It requires evaluators to identify a teacher-initiated question as clarifying (A1), lifting (A2), or summarizing (A3) and then categorize the question by topic. There are 14 coded topics in the tool (B1-B14). The observer follows the progress of the developing interaction by recording the type of student response to the teacher’s question as no response (C1), activity (C2), comment (C3), or question (C4). The teacher’s next response to the student action is then categorized in one of eight categories including no response (D1), repeating (D4), rephrasing (D5), follow-up statement (D6), goal-oriented redirecting (D7), and clarifying further (D8). To summarize, for each teacher-initiated question, an observer using the ISOCS records codes for four tiers of categorization: (A) question type, (B) topic, (C) student response, and (D) teacher response. An observed interaction code-string may cycle through the tiers multiple times since every question or response is individually coded (Brandon et al., 2008). Some of the data recorded with this tool would not fit the definition of a scaffolding interaction used in this study because a teacher might initiate a question on a topic and be greeted with no response and choose to not pursue the interaction.

Brandon et al. (2008) reported that inter-rater reliability data for experienced raters who used the full ISOCS for observation was not strong. The detailed assessment requires
multiple decisions and raters found distinctions between types of teacher initiated questions difficult to determine. In discussing their reliability results, the authors suggested drastic simplification of the coding tool. Specifically, they suggested eliminating the tier 1 or A-code observation of type of teacher question due to low reliability in coding and the tier 2 or B-code topic classification due to lack of relevance to their assessment goals. They further noted that the interaction that occurs in an inquiry science classroom is “primarily manifested” when students respond to the teacher with a comment, C3, coded in the third tier and the teacher engages the students in discussion through a follow-up statement, D6, or a clarifying statement, D8, as coded in the fourth tier. In their reliability testing data C3 codes comprised 90.4% of all tier 3 or C-code assignments, and the D6 and D8 codes comprised 78% of the tier 4 or D-code assignments that represented continued teacher/student engagement. The dominance of these categories in the reliability testing of the ISOCS implies that a more detailed focus on interactions, rather than simple questioning techniques is justifiable when assessing behavior during science courses taught using inquiry methodology. In fact in using the ISOCS to assess teacher behavior, the developers of the tool chose to calculate the percent of the recorded interactions that received codes C3 and D6 or D8 as a measure of adherence to an inquiry-based program.

Since the goal of this dissertation study was to examine only interactions that were two-way conversations between the students and instructors as a measurement of scaffolding behavior, a simplification of the ISOCS coding scheme that would yield reliable data was a good fit for data collection. Based on the detailed reliability data reported for the ISOCS, the authors’ suggestions for simplification, and the fact that interactions would be coded in a live classroom
without replay capability, I developed and tested a modified scheme in which classes of interactions were identified rather than longer coded strings of questions and responses. The data collected using my modified tool shows strong inter-rater reliability (IRR), as explained in the following paragraphs.

For the modified scheme, the ISOCS code string C3-D6, was identified as a follow-up interaction and the ISOCS code string C3-D8 was identified as a clarifying interaction. The ISOCS tier 1 or A-code categories of teacher question type were bypassed in preference for a focus on the predominant ISOCS tier 3 (C-code) and tier 4 (D-code) categories that describe a continuing interaction. ISOCS tier 2 (B-code) topical categories were not used, but a topical coding list that was refined during the pilot project to reflect topics discussed by university level students in a chemistry laboratory was used since this measure was pertinent to the planned study. The validity of the refined topical coding list is supported by data collected in an examination of student interactions during an open-inquiry general chemistry investigation reported by Krystyniak and Heikkinen (2007). The topics of interactions reported by Krystyniak and Heikkinen closely parallel those identified during the pilot project for this dissertation and incorporated into the modified tool.

The modified scheme for recording interactions between instructors and students in an inquiry-based laboratory setting was titled the Scaffolding Interaction Categorization Scheme (SICS). Figure 2 shows a schematic representation of the flow of coding decisions required when using the ISOCS and when using the SICS. Collection of the interaction data during the pilot project and extensive conversations with each observer individually and then in focus-group settings allowed careful development of descriptions of the types of interactions to aid in user
training and in a relevant list of interaction topics. There were over 300 hours of data collection and IRR testing during the pilot project which resulted in the development of the SICS and in SICS tool refinements.

*Figure 2.* Comparison of the flow of coding decisions for the ISOCS and the SICS. The SICS interaction type is based on ISOCS code strings C3-D6 and C3-D8.

During data collection for the research study, I performed IRR studies by silently observing each of the six TAs for two hours during three different laboratory sessions at the beginning, middle and end of the semester. The TAs and I independently recorded the number, type, and topic of interactions observed using the SICS. The first set of IRR data was collected during the second week of the semester in the acclimation period and was used as an additional training opportunity; the TA and I reconciled coding at the conclusion of each interaction during the collection process. For the second and third IRR sessions the TAs and I
independently coded the interactions. Later, the TAs coded interactions were compared to mine to establish reliability during data collection. Percent agreements reflect the consistency of coding. The percent agreement was calculated separately for the group of four TAs assisting the podcast treatment group and the group of two TAs assisting the lecture treatment group to assure that the observations in these two samples were consistent. These values are listed in Table 3 in four categories: agreement for number of interactions recorded, agreement for types of interactions recorded and agreement for topics and subtopics of interactions recorded. The values were calculated as follows:

\[ \frac{\sum \text{all aligned data points}}{\sum \text{all aligned data points} + \sum \text{data points not aligned}} \].

Table 3

*Inter-rater Reliability (IRR) for Scaffolding Interaction Data*

<table>
<thead>
<tr>
<th>TAs by section</th>
<th>IRR event</th>
<th>Percentage agreement for interactions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
</tr>
<tr>
<td>Podcast treatment</td>
<td>mid-semester</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>end-of-semester</td>
<td>.96</td>
</tr>
<tr>
<td>Lecture treatment</td>
<td>mid-semester</td>
<td>.96</td>
</tr>
<tr>
<td></td>
<td>end-of-semester</td>
<td>.90</td>
</tr>
</tbody>
</table>

The calculated IRR percentages show strong agreement for number, types and primary topics of the recorded interactions. There was less agreement on subtopics of the interactions; the TAs for the lecture treatment group assigned topics with a lower reliability rate than the TAs assisting the podcast treatment group. Discrepancies in subtopic categorization may be due to the fact that a single interaction might incorporate several subtopics and selecting the predominant subtopic in a live classroom setting is difficult. In future studies using this tool,
permitting assignment of multiple subtopic codes for a single interaction may increase subtopic reliability.

*Graded Laboratory Assignments*

The quizzes and final exam are locally written and are identical for all laboratory sections. They are open notebook objective tests that focus on central laboratory concepts, correct laboratory techniques and calculations essential to complete laboratory activities. Quiz question styles are multiple choice, short answer, and occasional brief description. TAs grade the quizzes using a key prepared by the faculty instructor that includes detailed partial credit assignments, when appropriate. The quizzes given during the dissertation project were tested during the pilot project to ensure that there were no typographical errors or questions that were unclear to a student population and that the grading keys were specific enough to allow even grading across all sections. A sample of six quizzes graded by each of the six TAs for a total of 36 graded quizzes that were administered during the dissertation project was randomly selected for IRR testing. I independently graded the quizzes and compared my recorded grades with the grades assigned by the TAs. The mean percentage difference between scores assigned by the four TAs grading the quizzes for the podcast treatment group and my assigned grades was –0.53% with a standard deviation of 2.76% and for the two TAs grading the quizzes for the lecture treatment group was –0.83% with a standard deviation of 1.87%. No grading judgments were required in evaluating the final exam since it was a multiple-choice exam.

Very specific rubrics were used for grading of the team lab reports and the individual student reflections. These rubrics have been developed over the past four years for use in evaluation of lab assignments at ACU. During the 2008 pilot project, multiple IRR tests were
performed using the rubrics and some of the categories were refined and described more specifically to enhance reliability of evaluation. Copies of the laboratory report and individual student reflection grading rubrics are included in Appendix B.

The 2009 TAs were trained in use of the grading rubrics and extensively coached as they graded during the first weeks of the semester. After this acclimation period, I randomly checked graded assignments each week, in my role as faculty instructor, and provided feedback to assure that the TAs continued to be vigilant about following the rubrics carefully. At the conclusion of data collection, a sample of six team lab reports and six corresponding student reflections graded by each of the six TAs was randomly selected for IRR testing. The mean percentage difference between scores assigned by the four TAs grading the 48 selected assignments from the podcast treatment group and my assigned scores was −0.55% with a standard deviation of 1.73% and for the two TAs grading the 24 selected assignments from the lecture treatment group was −0.55% with a standard deviation of 1.84%.

Field Notes

As the faculty instructor, I was present during each of the laboratory sessions used for data collection during this study. I took careful notes on the behavior of the students and TAs during the laboratory sessions paying close attention to any difficulties encountered. These notes provide some background for understanding the collected quantitative data.

Lecture Instructor Assessment of Motivation

Undoubtedly motivation plays a major role in student success. In an effort to account for this difficult-to-measure construct, the general chemistry lecture instructors were asked to categorize the behavior of each of their students as high, medium, or low motivation. The
students were classified based on the instructor’s observation of weekly lecture attendance and participation, completion of assigned work, and personal interactions in the classroom or during office hours. ACU general chemistry lecture course sizes are small ranging from 20-40 students. The lecture instructor has ample opportunity to observe individual student behavior throughout the 16-week semester. This categorization is qualitative in nature. The lecture instructor is the only individual who has the opportunity to closely observe individual behavior that reflects academic motivation for chemistry, therefore parallel evaluation by a second observer for the purposes of inter-rater reliability analysis is not possible. The instructors did discuss classification of students in an effort to standardize the evaluation consistently across the different lecture sections. Data collected for observed motivation was used in analysis of the treatment groups as a method of assessing comparability.

*End-of-course Survey*

All courses at ACU administer an end-of-course survey that serves as a faculty evaluation. In addition to Likert scale responses on questions about faculty effectiveness, there is a free response section. Student responses may provide some qualitative information about individual student opinions of the methods of course presentation that may have bearing on this study.

Dependent Variables

*Research Question 1*

The dependent variable for the first research question was the count data for student access to podcasts available during the laboratory period for the podcast treatment group. Activity logs for the file management system were used to determine the number of times a
podcast was accessed during relevant laboratory sessions. According to the research team role structure, the student whose assigned role was “Technician 2” was responsible for accessing the podcasts as a reference during team activities. A mean value of number of times podcasts were accessed per lab session per research team was determined. This provided evidence of the extent to which the student teams used the available podcasts.

Research Question 2

The dependent variables for the second research question were the number, type, and topics of the scaffolding interactions between student research teams and the instructors. These were measured using the SICS adapted from the interaction categories identified in the ISOCS. Instructors used the SICS to track interactions during the four-hour laboratory sessions in each of the six sections across the ten-week data collection window.

Research Question 3

The dependent variables for the third research question were the student outcome measures of the laboratory course grade, the mean team report and reflection grade, the mean quiz grade and the laboratory final exam grade for each student in the sample. These grades were collected by the instructors during the progress of the semester and harvested at the conclusion of the semester.

Independent Variable

The independent variable for the study was the method of delivery of general chemistry laboratory content. Four sections were selected to receive the information in the form of on-demand podcasts; students were not required to view the podcasts but could access them as
needed. Two sections were selected to receive the same information in the form of a traditional pre-laboratory lecture.

Data Analysis

All analyses were performed using the statistics program R (R Core Development Team, 2008). The standard statistical methods of measures of central tendency, $t$-test comparison, Pearson’s product-moment correlation (Pearson’s $r$), chi-square comparison, and analysis of variance (ANOVA) were used to process data. All testing for determining statistical significance was based on a two-tailed test of significance with $\alpha = .05$.

The study sample was described using percentages for categorical factors and mean and standard deviations for continuous variables. A chi-square test was used to compare the gender, observed motivation rating, and classification distributions of the two treatment groups. Pearson’s $r$ was calculated to characterize the correlation between the GALT test and ACT test scores and the earned course grade for the students in the sample. A Welch’s $t$-test was used to compare the mean GALT test and ACT test scores for the two treatment groups to determine whether they were statistically significantly different. The extent of podcast usage was described using frequency data and mean values for access events per research team and per experiment week. The instructor/research team interactions were described using frequency data, percentages, and mean values per research team and per experiment week. Welch’s $t$-tests were used to compare the mean interaction rates for the two treatment groups. The student outcome measures were described using mean values and standard deviations. Welch’s $t$-tests were used to compare the overall performance of the two treatment groups on
each outcome measure. A multi-way ANOVA was used to compare the performance of the treatment groups by factors and to investigate any interactions between factors.

Study Limitations

The greatest weakness of this study is external validity that may limit the ability to apply the study findings to other populations. Generalizability of the results to other general chemistry laboratory programs depends on the similarity of the study program to the target population. The curriculum used to teach the chemistry laboratories studied in this project was locally developed, though the activities were adapted from standard general chemistry experiments and the experiment format was modeled on the Science Writing Heuristic approach (Poock et al., 2007). The curriculum structure allowed flexibility and therefore local idiosyncrasies in implementation were inevitable. The study is strengthened by the quasi-experimental design; the two treatment groups were lead by the same instructor during the same semester using the same curriculum. All students in the study were enrolled in the parallel chemistry lecture course and all sections of the lecture course followed the same curriculum.

The TAs working in each of the laboratory sections were aware of the focus of the study but did not have any knowledge about the data collected during laboratory sessions other than their own. This independent data collection kept the TAs from being influenced by impressions they might have about the number, types, or topics of interactions or about level of graded work. Although they were trained in the methods of inquiry teaching, the data show that the undergraduate TAs collecting data during this study did not frequently engage students in follow-up interactions. As students with sophomore or junior standing, the TAs only had a year
or two of chemistry experience beyond that of the students they were assisting, and though they consistently helped students through clarifying interactions, the data reflect their hesitation to pursue higher-level interactions. This limits the conclusions that can be drawn about follow-up interactions from data and may also affect generalizability to laboratories taught exclusively by a faculty member.

Another factor that undoubtedly affected data on the numbers and types of student/instructor interactions was personality of the instructors and the students in the sample. The same faculty instructor led all sections during the study, but there were different TAs for each section. Careful TA training should have mitigated some personality differences and collection of data in multiple sections across ten weeks should have provided a leveling effect. The students worked in teams and systematically rotated roles within the teams. This should dilute the effect of strong student personalities. Future studies in different laboratory settings based on the results of this study will be needed to affirm the generalizability and the extent of external validity.

Possible threats to internal validity were construct validity, validity of the testing instruments, and statistical conclusion validity. The construct of the number, type, and topic of scaffolding interactions was measured using the SICS. The thorough description of the development of the ISOCS and its use in the assessment of behavior provide extensive background and convergent validity for the usefulness of the SICS in measuring instructor-student interactions. The locally prepared quizzes and final exam, as well as the structure of the required team lab reports and individual reflections had gone through multiple reviews by three faculty instructors with a total of 60 years of general chemistry teaching experience. The
grading rubrics were carefully developed and IRR studies affirmed their reliability. These processes addressed the validity of the testing instruments used to measure student performance in the laboratory course. The statistical approaches used in the study were very straightforward and the more conservative analyses were used in each case, contributing to statistical conclusion validity.

Summary

The topic of this study was the effectiveness of pertinent podcasts provided on-demand as a scaffolding support for students in a general chemistry laboratory. Podcasts were prepared on carefully chosen topics and reviewed by a podcast focus group before deployment. A pilot project was conducted to thoroughly test the data collection procedures and refine TA training.

Laboratories are traditionally taught using a pre-laboratory lecture format. For this study, two treatment groups were compared: a podcast treatment group and a pre-laboratory lecture treatment group. Method of delivery of essential laboratory information, either podcast or lecture, was the independent variable. Data were collected across a ten-week window through the first semester of a general chemistry laboratory course taught with an inquiry-based curriculum.

Two classes of dependent variables were investigated: number, type, and topics of student/instructor scaffolding interactions and student performance measures. Collected data was processed by looking at mean values of podcast usage, student/instructor interactions, and student performance measures for the two treatment groups to determine if any differences were evident. The results of this study should provide insight into the usefulness of podcasts as a scaffolding support to students in an introductory chemistry laboratory.
CHAPTER IV

RESULTS

Comparison of Treatment Groups

For the purposes of this study, students enrolled in four general chemistry laboratory sections were designated the podcast treatment group and students enrolled in two general chemistry laboratory sections were designated the lecture treatment group. A comparison of the student populations in the two research samples is important in determining whether there were evident differences that may bias the study outcomes. Mean GALT test scores and mean ACT scores for each treatment group were calculated and a t-test analysis was used to determine whether the means were statistically significantly different. Other factors used to describe the two groups were gender distributions, undergraduate classification distributions, as well as distribution of students that were identified by their general chemistry lecture instructors as students with high, medium or low motivation. Table 4 summarizes selected demographic data, mean GALT test and mean ACT test scores for each treatment group.

The mean GALT test score for the 81 students who completed the semester in the podcast treatment group was 9.32 (out of a possible 12 points) with a standard deviation of 2.00 and a range of 3-12. For the 51 students in the lecture treatment group who completed the semester the mean GALT test score was 9.00 with a standard deviation of 2.16 and a range of 1-12. A Fisher’s F test indicated that the variances of the GALT test scores for the two samples are not statistically significantly different ($F = 1.17$, numerator $df = 50$, denominator $df = 80$, $p = 0.52$). A Welch’s two-sample t-test was used for comparison of the mean scores of the samples in order to be more conservative in statistical approach. The results of the t-test
indicate that the mean GALT test scores of the groups would not be considered statistically significantly different at the $\alpha = .05$ level ($t = -0.85$, $df = 100.12$, $p = .39$). An analysis of the correlation between the GALT test score and the earned grade in the laboratory course for all students in this study gave a Pearson’s product-moment correlation value of $r = .41$ ($t = 5.15$, $df = 130$, $p < .001$).

Table 4

**Characteristics of the Treatment Groups**

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>ACT $\bar{X}$ $SD$</th>
<th>GALT $\bar{X}$ $SD$</th>
<th>Demographics by Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gender (M/F)</td>
</tr>
<tr>
<td>Podcast ($n = 81$)</td>
<td>25.96 3.84</td>
<td>9.32 2.00</td>
<td>F 56.8%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M 43.2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Low 18.5%</td>
</tr>
<tr>
<td>Lecture ($n = 51$)</td>
<td>25.20 3.27</td>
<td>9.00 2.16</td>
<td>F 60.8%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M 39.2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Low 21.6%</td>
</tr>
</tbody>
</table>

A Welch’s $t$-test was also used for comparison of the mean ACT test scores for the treatment groups. The mean ACT test score for the students in the podcast treatment group was 25.96 with a standard deviation of 3.84 and a range of 16-35. Students in the lecture treatment group had a mean ACT test score of 25.20 with a standard deviation of 3.27 and a range of 20-32. The $t$-test results indicate that the difference between the means was not statistically significant at the $\alpha = .05$ level ($t = -1.23$, $df = 118.64$, $p = .22$). A Fisher’s $F$ test comparing the variances of the treatment groups indicated that there was not a significant difference in the variances ($F = .72$, numerator $df = 50$, denominator $df = 80$, $p = .22$). An
analysis of the correlation between the ACT test score and the earned grade in the laboratory
course for the students in this study gave a Pearson’s product-moment correlation value of $r = .57$ ($t = 7.92$, $df = 130$, $p < .001$).

As listed in Table 4, the gender, observed motivation rating, and classification
distributions of the two treatment samples were very similar. The podcast treatment group was
56.8% female and 43.2% male while the lecture treatment group was 60.8% female and 39.2%
males. Chi-square analysis indicated that the gender distributions for the treatment groups were
not statistically significantly different ($\chi^2 = 0.074$, $df = 1$, $p = .76$). The lecture instructors rated
40.7% of the podcast treatment group and 39.2% of the lecture treatment group as highly
motivated, 40.7% of the podcast treatment group and 39.2% of the lecture treatment group as
students with mid-range motivation, and 18.5% of the podcast treatment group and 21.6% of
the lecture treatment group as students exhibiting low motivation. Chi-square analysis
indicated that the motivation distributions for the treatment groups were not statistically
significantly different ($\chi^2 = 0.18$, $df = 2$, $p = .91$). Freshmen comprised 72.5% of the lecture
treatment group and 75.6% of the podcast treatment group. Sophomores comprised 15.7% of
the lecture treatment group and 15.8% of the podcast treatment group. The lecture treatment
group also included 7.8% juniors and 3.9% seniors compared to a 7.3% junior and 1.2% senior
presence in the podcast treatment group. Chi-square analysis indicated that the distribution of
freshmen and students of other classifications in the two treatment groups were not
statistically significantly different ($\chi^2 = 0.096$, $df = 1$, $p = .76$).

In summary, the podcast treatment and lecture treatment groups showed no significant
differences in the mean values of the GALT test measure collected at the beginning of the
semester or the ACT test scores harvested from entrance examination data in the university database. Variances of the GALT test scores and ACT test scores were not statistically significantly different in the two treatment groups. The student populations in each group had very similar gender, classification and observed motivation assessment distributions. Based on the factors examined, there were no statistically significant differences in the two samples that might skew data collection or results.

First Research Question: Extent of Podcast Usage

Data Analysis

The first research question addressed how frequently student research teams voluntarily retrieved relevant chemistry podcasts made available for on-demand access during a general chemistry laboratory taught with an inquiry-based curriculum. The data analyzed in investigating this question were gathered from access logs generated by the file management system used to house the podcasts. The logs listed the time of access and the name of the individual gaining access. Podcasts were released for viewing during the meeting times for sections designated as part of the podcast treatment group. Only students enrolled in these sections could gain access to the podcasts by logging into the class file using their university issued username and personal password.

Podcasts were available during seven weeks of the ten-week interaction data collection window. Table 5 lists the number of access events and mean access events per research team by experiment week for the podcasts that were available and used during this window. While student research teams did access all of the prepared podcasts during the semester, several were only used during the first two weeks of the semester in the acclimation period before data
collection began. The podcasts in this category include “Using a Crucible”, “Determining Significant Figures” and “Reading Liquid Levels.”

Table 5

Summary of Podcast Usage by Experiment Week

<table>
<thead>
<tr>
<th>Experiment Week</th>
<th>Accessed podcasts</th>
<th>Total access events</th>
<th>Mean access events per team</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Vernier® Gas Pressure Equipment</td>
<td>32</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>Collecting a Gas Sample</td>
<td>32</td>
<td>1.33</td>
</tr>
<tr>
<td></td>
<td>Using Pipets</td>
<td>39</td>
<td>1.63</td>
</tr>
<tr>
<td></td>
<td>Simple Statistics</td>
<td>63</td>
<td>2.63</td>
</tr>
<tr>
<td>4</td>
<td>Filtering</td>
<td>28</td>
<td>1.17</td>
</tr>
<tr>
<td></td>
<td>Mass Determination</td>
<td>11</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>Simple Statistics</td>
<td>8</td>
<td>0.33</td>
</tr>
<tr>
<td>5</td>
<td>Comparing Reactivity of Metals</td>
<td>53</td>
<td>2.21</td>
</tr>
<tr>
<td></td>
<td>Using Acids Safely</td>
<td>39</td>
<td>1.63</td>
</tr>
<tr>
<td>8</td>
<td>Using Pipets</td>
<td>7</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>Titration Techniques</td>
<td>46</td>
<td>1.92</td>
</tr>
<tr>
<td>9</td>
<td>Filtering</td>
<td>45</td>
<td>1.88</td>
</tr>
<tr>
<td></td>
<td>Using Acids Safely</td>
<td>4</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>Simple Statistics</td>
<td>4</td>
<td>0.17</td>
</tr>
<tr>
<td>10</td>
<td>Planning an Experiment</td>
<td>59</td>
<td>2.46</td>
</tr>
</tbody>
</table>

The first column in Table 5 gives the experiment week and the second column lists the titles of the specific podcasts accessed by at least 1 of the 24 teams in the podcast treatment group during that week. The third column lists the count data for podcast usage events as compiled from the access logs that were generated daily. Occasionally a research team accessed the same podcast several times within a short period of time. For the purposes of the podcast count data, if a team member accessed a podcast less than 8 minutes after another log
entry in their own name or a team member’s name, the access was not counted as an additional usage event. Since the longest podcast is about 5 minutes in length this allows a minimum 3-minute buffer between counted events.

There were 24 research teams that worked in podcast treatment laboratory sections. As part of the curriculum design, students were required to work cooperatively within their teams to plan and implement the experiments. They followed assigned group roles. One of responsibilities of Technician 1 in each research team was pulling up podcasts for the team; however, all students in a podcast treatment section with a device had access to the podcasts. By comparing the names of the students on the access logs with the list of students in each research team, it was possible to determine whether side-by-side access within research teams had occurred. On the occasions when log entries show that two students in the same research team accessed a podcast in the same time block, only one access event was recorded. The fourth column in Table 5 lists the mean number of access events for each podcast that was accessed per research team each week.

Table 6 summarizes the total usage by podcast title for those podcasts accessed during data collection. The podcasts are listed by access rates in ascending order. Column two shows the total count data for the individual podcast access events and column three contains the mean number of access events per team \( n = 24 \) across the seven weeks that podcasts were available.
Table 6

Podcast Access Events by Podcast Title

<table>
<thead>
<tr>
<th>Accessed Podcasts</th>
<th>Team access events</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>total</td>
<td>$\bar{x}$ (per team $n = 24$)</td>
</tr>
<tr>
<td>Simple Statistics</td>
<td>75</td>
<td>3.13</td>
</tr>
<tr>
<td>Filtering</td>
<td>73</td>
<td>3.04</td>
</tr>
<tr>
<td>Planning an Experiment</td>
<td>59</td>
<td>2.46</td>
</tr>
<tr>
<td>Comparing Reactivity of Metals</td>
<td>53</td>
<td>2.21</td>
</tr>
<tr>
<td>Using Pipets</td>
<td>46</td>
<td>1.92</td>
</tr>
<tr>
<td>Titration Techniques</td>
<td>46</td>
<td>1.92</td>
</tr>
<tr>
<td>Using Acids Safely</td>
<td>43</td>
<td>1.79</td>
</tr>
<tr>
<td>Vernier® Gas Pressure Equipment</td>
<td>32</td>
<td>1.33</td>
</tr>
<tr>
<td>Collecting a Gas Sample</td>
<td>32</td>
<td>1.33</td>
</tr>
<tr>
<td>Mass Determination</td>
<td>11</td>
<td>0.46</td>
</tr>
</tbody>
</table>

Discussion

Podcasts that covered basic chemistry laboratory techniques, concepts and calculations were made available for student use. When teaching sections that had podcast access, instructors pointed out those that contained information that might be particularly useful for the assigned activities. Instructors would occasionally remind the student teams that podcasts were available during the laboratory session particularly if they seemed to be struggling. Though they were encouraged to use the prepared podcasts as a resource, the research teams were not required to watch them. During the laboratory sessions of the week when titration was used for analyzing antacids, all of the student research teams did watch the podcast.
covering titration before going in to the laboratory room. An informal show of hands indicated that only a few of the enrolled students had used the technique previously.

The quantitative data indicate that student research teams accessed podcasts regularly during each experiment week for which data were collected. The podcasts can be grouped into those that covered laboratory techniques and those that covered calculations or concepts. Podcasts that presented information about laboratory techniques that were accessed during the data collection window were “Vernier® Gas Pressure Equipment,” “Collecting a Gas Sample,” “Using Pipets,” “Filtering,” “Mass Determination,” “Using Acids Safely,” and “Titration Techniques.” Across the data collection period, the mean number of access events per research team during a laboratory session for podcasts covering a laboratory technique was 1.68 per experiment week. Calculations or concepts were the topic of the podcasts titled “Simple Statistics,” “Comparing Reactivity of Metals,” and “Planning an Experiment.” On average, these podcasts were accessed 1.12 times per research team per experiment during the data collection window. The lower mean value across the duration of the data collection for the podcasts covering calculations or concepts reflects the fact that there were fewer podcasts available in this category. The overall mean number of access events per research team per experiment for podcasts in either category was 2.80; on average student research teams accessed a podcast approximately three times per laboratory period.

The extent to which the individual podcasts were used is uneven. This inequity is partially the result of the fact that some podcasts were pertinent for a single laboratory session while others covered topics that were important for several experiments and were accessed during multiple laboratory sessions. Another factor that affected extent of usage was the
familiarity of the topics. Some podcasts covered topics that were familiar to most students such as “Mass Determination” and others covered topics that were new to a significant portion of the student population such as “Titration Techniques.”

While conclusions cannot be drawn about which podcasts were most useful to students from count data, the most used podcasts can be identified. It is interesting that three of the four most used podcasts were the three podcasts covering calculations or concepts. These were “Simple Statistics,” “Planning an Experiment,” and “Comparing Reactivity of Metals.” Of these three, only “Simple Statistics” was accessed during more than one experiment week. “Simple Statistics” still falls in the third most used position with 2.63 access events per research team even if only the data from the first week it was accessed is considered. Thus, the data indicate that the podcasts that covered calculations and concepts were used most frequently. The one podcast that covered a technique that was accessed more than 2.00 times per team over the data collection window was “Filtering.”

Weekly trends in usage for the different podcast topics can also be observed. As expected from total usage data, podcasts that covered calculations or concepts were accessed at the highest weekly rates. The range of mean values for access to these podcasts per research team during a single week is 2.21-2.63 for the first week access was observed. As mentioned previously, “Simple Statistics” was accessed during multiple weeks. During Week 4 the mean access count was 2.63 per team, during Week 5 it was 0.33 per team and during Week 10 it was 0.17 per team. As might be expected, usage diminished as students gained more laboratory experience.
The data show that podcasts that covered a laboratory technique had lower weekly access rates than those that covered calculations or concepts. The range of mean values for access to these podcasts per research team during a single week in the data collection period was 0.45-1.88. Once again, several podcasts in this category were accessed during multiple experiment weeks and a pattern of diminished usage with increasing laboratory experience is evident. “Pipets” was accessed 1.63 times per team during Week 4, but only 0.29 times per team during Week 7, while “Using Acids Safely” was accessed 1.63 times per team during Week 8 and then only 0.17 times per team during Week 10. The one podcast that was accessed multiple times that does not fit the diminishing usage trend is “Filtering.” This particular podcast covered two unique filtering techniques. One filtering technique was used during experiment Week 5 when the usage rate was 1.17 times per team and the other filtering technique was used during Experiment Week 10 when the mean usage rate was 1.88 access events per team.

The results of the data analysis clearly indicate regular use of the prepared podcasts throughout the data collection period. Uneven podcast usage can be explained by the variety of topics covered by the podcasts and the variety of activities that were a part of the curriculum as well as the variation in student experience in laboratories before enrollment in the General Chemistry I Laboratory course.

Second Research Question: Comparison of Instructor/Research Team Interactions

_Data Analysis_

The second research question addressed what differences were evident in the number, types, and topics of scaffolding interactions between student research teams and instructors in
laboratory sections that had access to on-demand podcasts but no pre-laboratory lecture and those who had been instructed using a traditional pre-laboratory lecture. Instructors of the sections that participated in this study recorded every scaffolding interaction during all laboratory sessions within the data collection window. Instructors also determined the type and topic of the interactions using the Scaffolding Interaction Coding Scheme (SICS) developed for this study and described in Chapter III.

Table 7 shows the count data on types of scaffolding interactions for the two treatment groups listed by experiment week. The research design incorporated an interrupted time series investigation. The podcast treatment group had access to podcasts during seven of the ten weeks of data collection and during Weeks 6, 7, and 12 the podcast treatment group did not have podcast access but received a pre-laboratory lecture. During Week 4 the podcast treatment group had podcast access and received a pre-laboratory lecture that covered the material presented in one of the podcasts that was accessed by student research teams ("Gas Collection"). The lecture treatment group received a pre-laboratory lecture each week and never had podcast access. In Table 7, on page 81, the data collected when both of the treatment groups received lectures only (Weeks 6, 7, and 12) is labeled “equivalent treatment.” The data collected when groups received different treatments (Weeks 3, 4, 5, 8, 9, 10, and 11) is labeled “contrasting treatment.”

The two types of scaffolding interactions recorded by the instructors were clarifying interactions and follow-up interactions. An instructor provided assistance to help a research team accomplish their experimental goals and encouraged them to successfully complete their activity through a clarifying interaction. Clarifying interactions focused on the task at hand and
**Table 7**

*Types of Scaffolding Interactions by Experiment Week*

<table>
<thead>
<tr>
<th>Experiment Week: Treatment Block</th>
<th>Clarifying Interactions</th>
<th></th>
<th>Follow-up Interactions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>total</td>
<td>( \bar{x} ) (per team)</td>
<td>total</td>
<td>( \bar{x} ) (per team)</td>
</tr>
<tr>
<td>Week 3: Contrasting Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>96</td>
<td>4.00</td>
<td>22</td>
<td>0.92</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>63</td>
<td>4.50</td>
<td>6</td>
<td>0.43</td>
</tr>
<tr>
<td>Week 4: Contrasting Treatment*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>96</td>
<td>4.00</td>
<td>15</td>
<td>0.63</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>59</td>
<td>4.21</td>
<td>7</td>
<td>0.50</td>
</tr>
<tr>
<td>Week 5: Contrasting Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>62</td>
<td>2.58</td>
<td>8</td>
<td>0.33</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>62</td>
<td>4.43</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>Week 6: Equivalent Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>39</td>
<td>1.63</td>
<td>8</td>
<td>0.33</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>19</td>
<td>1.35</td>
<td>2</td>
<td>0.14</td>
</tr>
<tr>
<td>Week 7: Equivalent Treatment</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
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<td>1.70</td>
<td>17</td>
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</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>28</td>
<td>2.00</td>
<td>4</td>
<td>0.29</td>
</tr>
<tr>
<td>Week 8: Contrasting Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>65</td>
<td>2.71</td>
<td>19</td>
<td>0.79</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>67</td>
<td>4.78</td>
<td>1</td>
<td>0.07</td>
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<td>Week 9: Contrasting Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>71</td>
<td>2.95</td>
<td>5</td>
<td>0.21</td>
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<tr>
<td>Lecture teams (n = 14)</td>
<td>63</td>
<td>4.42</td>
<td>5</td>
<td>0.36</td>
</tr>
<tr>
<td>Week 10: Contrasting Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>80</td>
<td>3.33</td>
<td>2</td>
<td>0.08</td>
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<tr>
<td>Lecture teams (n = 14)</td>
<td>80</td>
<td>5.71</td>
<td>5</td>
<td>0.36</td>
</tr>
<tr>
<td>Week 11: Contrasting Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>50</td>
<td>2.08</td>
<td>11</td>
<td>0.46</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>42</td>
<td>3.00</td>
<td>2</td>
<td>0.14</td>
</tr>
<tr>
<td>Week 12: Contrasting Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>60</td>
<td>2.50</td>
<td>38</td>
<td>1.58</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>36</td>
<td>2.57</td>
<td>14</td>
<td>1.00</td>
</tr>
</tbody>
</table>

*The podcast treatment group had podcast access plus a pre-laboratory.*
encompassed interactions about concepts as well as how to carry out a procedure or technique and how to use formulae or correctly complete calculations. A follow-up interaction, as defined for this study, was an interaction through which an instructor attempted to guide the student team to a new level of understanding connecting with ideas from previous experiments or related concepts.

The count data on types of interactions clearly indicate that clarifying interactions were the predominant interaction between instructor and students in research teams for both treatment groups during this study. The mean ratio of clarifying interactions to follow-up interactions for data collected in all laboratory sessions was 15:1. Due to the limited amount of data collected on follow-up interactions most data analysis focuses on clarifying interactions, but some general trends in follow-up interactions can be noted.

Table 7 shows totals per week, but also shows the mean number of instructor/research team interactions per research team by type. The mean values for the per-team follow-up interactions across the data collection window were 0.60 with a standard deviation of 0.43 for the podcast treatment group and 0.33 with a standard deviation of 0.29 for the lecture treatment group. A Welch’s t-test indicates that there was not a statistically significant difference in the number of follow-up interactions for the research teams in the podcast treatment group when they had access to podcasts when compared with the research teams in the lecture treatment group when they received a pre-laboratory lecture \( t = -1.50, df = 7.44, p = .17 \).

The relationship between numbers of clarifying interactions and numbers of follow-up interactions was investigated by looking at statistical expressions of correlation. It might be
expected that as the necessity for clarifying interactions decreased, the instructors would be more available and as a result the number of follow-up interactions might increase. In fact, the correlation between the mean number of clarifying interactions and number of follow-up interactions during all experiment weeks does show a negative correlation with a Pearson’s $r$ value of $-.22$ but the corresponding $r^2$ value is only $.050$ indicating an extremely weak relationship.

The volume of data collected on clarifying interactions allowed a much more thorough analysis of the treatment effects on numbers and topics of this type of instructor/research team interactions. Mean values for the weekly per-team clarifying interactions across the data collection window were 2.74 with a standard deviation of 0.84 for the podcast treatment group and 3.70 with a standard deviation of 1.39 for the lecture treatment group. Figure 3 is a graphical representation of the mean number of clarifying interactions per research team by experiment week as listed in Table 7.

For the purpose of data analysis, the data collected when both of the treatment groups received lectures only (Weeks 6, 7, and 12) can be grouped together. This group of data was the equivalent treatment block and will be used as a baseline comparison for the data collected when the groups received different treatments or the contrasting treatment block (Weeks 3, 5, 8, 9, 10, and 11). During Week 4, some information was presented to the podcast treatment group in lecture format, but they also had access to podcasts, so data from this week will be treated separately and labeled mixed treatment. Examination of the data displayed in Figure 3 shows that during equivalent treatment weeks and during mixed treatment (Week 4) the rates of clarifying interactions per team were close in value. The rates of clarifying interactions during
the contrasting treatment weeks show greater differences. Table 8 lists overall mean values and standard deviations for rates of clarifying interactions for each treatment group organized by treatment blocks.

Figure 3. Mean numbers of clarifying interactions per research team by experiment week shown for the lecture treatment group (number of research teams in the group \( n = 24 \)) and the podcast treatment group (number of research teams in the group \( n = 14 \)).

Table 8

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Mean clarifying interactions per research team</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Contrasting treatment (Weeks 3, 5, 8, 10, 11)</td>
<td>Equivalent treatment (Weeks 6, 7, 12)</td>
<td>Mixed treatment (Week 4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>( \bar{X} )</td>
<td>( SD )</td>
<td>( \bar{X} )</td>
<td>( SD )</td>
</tr>
<tr>
<td>Podcast treatment teams ((n = 24))</td>
<td>2.94</td>
<td>0.66</td>
<td>1.94</td>
<td>0.49</td>
</tr>
<tr>
<td>Lecture treatment teams ((n = 14))</td>
<td>4.48</td>
<td>0.87</td>
<td>1.98</td>
<td>0.61</td>
</tr>
</tbody>
</table>
Examination of data from Table 7 shows that during each of the contrasting treatment weeks, the mean per-team clarifying interaction rate was higher for the lecture treatment group than for the podcast treatment group. The mean values given in Table 8 show that instructors recorded an average of 1.54 more interactions per week per team for the lecture treatment group during experiment weeks with contrasting treatments. The range of differences was 0.50-2.38 interactions per week per team. A Welch’s t-test indicates that this difference was statistically significant at the $\alpha = .05$ level ($t = 3.49$, $df = 9.48$, $p = .0063$).

One standard way of describing the size of a difference that may be due to the effect of a treatment is an effect size. Cohen’s $d$ is an expression of effect size and can be calculated using the formula:

$$d = (\bar{X}_t - \bar{X}_c) / S_{\text{pooled}}$$

where $d =$ effect size, $\bar{X}_t =$ mean of the first treatment group, $\bar{X}_c =$ mean of the second treatment group and $S_{\text{pooled}} =$ pooled standard deviation (Thalheimer & Cook, 2002). Cohen’s $d$ calculated for mean clarifying interaction data collected during contrasting treatment weeks is 2.18. An effect size over .80 is considered a large effect size (Thalheimer & Cook, 2002). This is a quantitative expression comparing the effect of the podcast treatment to lecture treatment on the number of recorded clarifying interactions.

The mean per-team clarifying interaction rates for the two treatment groups during equivalent treatment weeks were close in value differing by only 0.035 interactions. During Week 6 the podcast group rate was 0.27 higher, during Week 7 the lecture treatment group rate was 0.30 higher and during Week 12 the interaction rates differ by only 0.07 interactions. As expected, a Welch’s t-test indicates no statistically significant difference at the $\alpha = .05$ level.
(t = .078, df = 3.82, p = .94). It is interesting that the interaction rates for Week 4, when the podcast treatment group received a “mixed” treatment, are aligned with the data for the weeks when equivalent treatment was offered; the difference in interaction rates was 0.26 interactions per team and the lecture treatment group had the higher interaction rate.

In addition to recording the type of scaffolding interactions, the instructors recorded the primary topic and subtopic of the interactions. Table 9 summarizes the primary topic data for all clarifying interactions. The primary topics were divided by the activity that was the focus of the interaction. An interaction between an instructor and research team that was focused on material on the initial worksheet used to introduce students to important background information was categorized as a “Q” interaction. An interaction focused on the experiment that was being planned or performed was categorized as an “E” interaction. Interactions that centered on the processing of data or integration of information learned from data as the research teams worked on the team laboratory reports were categorized as “P” interactions. Inter-rater reliability studies give us confidence that the primary topics were recorded with consistency across the different laboratory sections during data collection.

Inspection of the data in Table 9 shows that during most experiment weeks the majority of clarifying interactions centered on the planning and execution of the laboratory experiment. This was true in laboratory sessions for both treatment groups. Exceptions occur in experiment Weeks 6 and 7; during these weeks the initial inquiry activities were longer than usual and the time spent conducting the experiments was shorter in duration. Table 10 gives ten-week totals for the primary topics of clarifying interactions and lists them by percentage of the total.
### Table 9

**Primary Topics of Clarifying Interaction by Experiment Week**

<table>
<thead>
<tr>
<th>Experiment Week: Treatment Block</th>
<th>Total clarifying interactions by topic</th>
<th>Mean clarifying interactions per research team by topic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q</td>
<td>E</td>
</tr>
<tr>
<td><strong>Week 3: Contrasting Treatment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>17</td>
<td>65</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>7</td>
<td>43</td>
</tr>
<tr>
<td><strong>Week 4: Contrasting Treatment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>12</td>
<td>72</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>7</td>
<td>43</td>
</tr>
<tr>
<td><strong>Week 5: Contrasting Treatment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>24</td>
<td>35</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>21</td>
<td>39</td>
</tr>
<tr>
<td><strong>Week 6: Equivalent Treatment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>37</td>
<td>2</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>19</td>
<td>0</td>
</tr>
<tr>
<td><strong>Week 7: Equivalent Treatment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>26</td>
<td>15</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td><strong>Week 8: Contrasting Treatment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>11</td>
<td>42</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>11</td>
<td>39</td>
</tr>
<tr>
<td><strong>Week 9: Contrasting Treatment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>14</td>
<td>53</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>11</td>
<td>48</td>
</tr>
<tr>
<td><strong>Week 10: Contrasting Treatment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>21</td>
<td>58</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>19</td>
<td>59</td>
</tr>
<tr>
<td><strong>Week 11: Contrasting Treatment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>15</td>
<td>27</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>7</td>
<td>30</td>
</tr>
<tr>
<td><strong>Week 12: Equivalent Treatment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Podcast teams (n = 24)</td>
<td>0</td>
<td>60</td>
</tr>
<tr>
<td>Lecture teams (n = 14)</td>
<td>0</td>
<td>36</td>
</tr>
</tbody>
</table>

*Note.* Mean values cannot be calculated if the total number of interactions is zero. The mean values in these cases are represented by a dash (–).

*The podcast treatment group had podcast access and received a pre-laboratory lecture during Week 4.*
Table 10

*Topic Distributions of Clarifying Interactions*

<table>
<thead>
<tr>
<th>Group</th>
<th>Clarifying interactions during data collection (percentage of the total)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>Podcast treatment</td>
<td>660</td>
</tr>
<tr>
<td></td>
<td>(100%)</td>
</tr>
<tr>
<td>Lecture treatment</td>
<td>518</td>
</tr>
<tr>
<td></td>
<td>(100%)</td>
</tr>
</tbody>
</table>

Mean values per research team per week by topic also show the dominance of the clarifying interactions during the time when students were conducting experiments (coded as E interactions). Figure 4 is a graphical representation of the means values of clarifying interactions coded as E interactions across the data collection window. Notice that there is little difference in the rate of E interactions between the two treatment groups during each week in the equivalent treatment block and during Week 4 when the podcast treatment group received a mixed treatment.

Table 11 shows the breakdown of clarifying interactions by primary topic and by treatment blocks. Weeks 6 and 7, when the inquiry activities preceding the laboratory experiment were much longer, are included in the equivalent treatment block. The data from these weeks causes the mean value for Q interactions to be higher than the mean value for E interactions for laboratory sessions in the equivalent treatment block.
Figure 4. Mean number of E clarifying interactions per research team by experiment week for the lecture treatment group (number of research teams, $n = 14$) and podcast treatment group (number of research team, $n = 24$).

Table 11

**Topics of Clarifying Interactions per Research Team by Treatment Block**

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Contrasting treatment (Weeks 3, 5, 8, 9, 10, 11)</th>
<th>Equivalent treatment (Weeks 6, 7, 12)</th>
<th>Mixed treatment (Week 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>E</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>podcast treatment teams ($n = 24$)</td>
<td>0.71 (0.20)</td>
<td>1.94 (0.60)</td>
<td>0.29 (0.22)</td>
</tr>
<tr>
<td>lecture treatment teams ($n = 14$)</td>
<td>0.91 (0.43)</td>
<td>3.07 (0.70)</td>
<td>0.50 (0.46)</td>
</tr>
</tbody>
</table>

Simple inspection of the values in Table 11 leads to the conclusion that the clarifying interaction rates by topic for the laboratory sessions in the equivalent treatment block and for Week 4 were not different for the two treatment groups. The mean values for Q interactions
differed by only 0.02 events during equivalent treatment and were identical during Week 4. The mean values for E interactions differed by just 0.08 events during equivalent treatment and 0.01 during Week 4. Neither group had recorded P interactions during equivalent treatment, but during Week 4 the P interaction rates differed by 0.14.

A Welch’s t-test can be used to compare the topical mean values per team per week for the treatment groups within the contrasting treatment block. Rates for clarifying interactions centered on the inquiry worksheet (Q interactions) are not statistically significantly different at the $\alpha = .05$ level ($t = -1.02, df = 7.053, p = .34$). Interactions focused on processing of data or integration of information learned from data (P interactions) are not significantly different for the two treatment groups at the $\alpha = .05$ level ($t = -1.02, df = 7.15, p = .34$). Only clarifying interactions that focused on the experiment that was being planned or performed (E interactions) are significantly different at the $\alpha = .05$ level according to a Welch’s t-test ($t = 2.99, df = 9.79, p = .014$). Cohen’s $d$ calculated as an expression of effect size using data for the E interactions only gives a value of 1.73. This would be considered a very large effect size.

Table 12 lists the count data collected on subtopic categories with mean values per research team per experiment week. Inter-rater reliability studies indicated that though the data for numbers, types, and topics of interactions were collected with high reliability, the data for subtopics were collected with less accuracy than would be desired. Conclusions based on these data must be limited due to uncertainty about the consistency of data collection across all laboratory sections, however some general trends can be observed. Table 13 lists total and mean values per team for interactions by subtopic for both treatment groups across the data collection window. (For reference, the SICS subtopics are listed on pages 34 and 59.)
### Table 12

**Subtopics of Clarifying Interactions by Treatment Group by Experiment Week**

<table>
<thead>
<tr>
<th>Experiment Week: Treatment Block</th>
<th>Clarifying Interactions by Subtopic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q1</td>
</tr>
<tr>
<td></td>
<td>total</td>
</tr>
<tr>
<td><strong>Week 3: Contrasting Treatment</strong></td>
<td></td>
</tr>
<tr>
<td>Podcast teams ($n=24$)</td>
<td>3</td>
</tr>
<tr>
<td>Lecture teams ($n=14$)</td>
<td>2</td>
</tr>
<tr>
<td><strong>Week 4: Contrasting Treatment</strong></td>
<td></td>
</tr>
<tr>
<td>Podcast teams ($n=24$)</td>
<td>9</td>
</tr>
<tr>
<td>Lecture teams ($n=14$)</td>
<td>6</td>
</tr>
<tr>
<td><strong>Week 5: Contrasting Treatment</strong></td>
<td></td>
</tr>
<tr>
<td>Podcast teams ($n=24$)</td>
<td>5</td>
</tr>
<tr>
<td>Lecture teams ($n=14$)</td>
<td>10</td>
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<tr>
<td><strong>Week 6: Equivalent Treatment</strong></td>
<td></td>
</tr>
<tr>
<td>Podcast teams ($n=24$)</td>
<td>27</td>
</tr>
<tr>
<td>Lecture teams ($n=14$)</td>
<td>14</td>
</tr>
<tr>
<td><strong>Week 7: Equivalent Treatment</strong></td>
<td></td>
</tr>
<tr>
<td>Podcast teams ($n=24$)</td>
<td>2</td>
</tr>
<tr>
<td>Lecture teams ($n=14$)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Week 8: Contrasting Treatment</strong></td>
<td></td>
</tr>
<tr>
<td>Podcast teams ($n=24$)</td>
<td>0</td>
</tr>
<tr>
<td>Lecture teams ($n=14$)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Week 9: Contrasting Treatment</strong></td>
<td></td>
</tr>
<tr>
<td>Podcast teams ($n=24$)</td>
<td>4</td>
</tr>
<tr>
<td>Lecture teams ($n=14$)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Week 10: Contrasting Treatment</strong></td>
<td></td>
</tr>
<tr>
<td>Podcast teams ($n=24$)</td>
<td>8</td>
</tr>
<tr>
<td>Lecture teams ($n=14$)</td>
<td>4</td>
</tr>
<tr>
<td><strong>Week 11: Contrasting Treatment</strong></td>
<td></td>
</tr>
<tr>
<td>Podcast teams ($n=24$)</td>
<td>0</td>
</tr>
<tr>
<td>Lecture teams ($n=14$)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Week 12: Equivalent Treatment</strong></td>
<td></td>
</tr>
<tr>
<td>Podcast teams ($n=24$)</td>
<td>0</td>
</tr>
<tr>
<td>Lecture teams ($n=14$)</td>
<td>0</td>
</tr>
</tbody>
</table>

*During Week 4 the podcast treatment group had access to podcasts and received a lecture*
Table 13

Subtopics of Clarifying Interactions by Treatment Group

<table>
<thead>
<tr>
<th>Group</th>
<th>Clarifying interactions by subtopic across data collection window (Mean per team)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Q1</td>
</tr>
<tr>
<td>Podcast treatment teams (n = 24)</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>(2.42)</td>
</tr>
<tr>
<td>Lecture treatment teams (n = 14)</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>(2.64)</td>
</tr>
</tbody>
</table>

Discussion

Data were collected on the number, types, and topics of scaffolding interactions between student research teams and instructors in laboratory sections designated as the podcast treatment group and sections designated as the lecture treatment group. During experiment weeks that were part of the equivalent treatment block, all sections received a pre-laboratory lecture and no sections had access to podcasts. During experiment weeks that were part of the contrasting treatment block, the podcast treatment group had access to on-demand podcasts but no pre-laboratory lecture and the lecture treatment group was instructed using a traditional pre-laboratory lecture. The podcast treatment group received a mixed treatment during Week 4 since students had access to podcasts and the instructor lectured over the material contained in one of the podcasts accessed by students (“Collecting a Gas Sample”). Instructors of the sections participating in this study recorded every scaffolding interaction...
during all laboratory sessions during the data collection window. Instructors also determined
the type and topic of the interactions using the SICS developed for this study.

The majority of interactions recorded for both treatment groups were clarifying
interactions. Although there were follow-up interactions recorded, the volume of data was so
small that caution should be used in drawing any conclusions about patterns in frequency or
topics. The imbalance in the types of interactions may be explained by two factors. First,
students participating in an inquiry-based curriculum for the first time may need much support
in the form of clarifying interactions. When the instructor’s time was focused on assisting
students through basic laboratory techniques or experiment planning, they may not have had
time to engage students in more abstract follow-up interactions. If the lack of adequate time
strongly influenced the probability of follow-up interactions occurring, a negative correlation
between number of clarifying interactions and number of follow-up interactions would have
been expected. The correlation coefficient for these two variables is negative but is so small
that it is nearly negligible. This indicates that during this study the number of clarifying
interactions did not seem to influence the number of follow-up interactions.

A second factor that may have caused the imbalance in types of interactions was the
preparation and confidence of the undergraduate students who served as the teaching
assistants. Most of the teaching assistants were sophomore or junior undergraduate
biochemistry majors and none of them had served as a teaching assistant previously. Though
they had completed the curriculum and were capable of helping students with the assigned
work, they were peers who were only a few steps beyond the general chemistry students in
chemistry knowledge. Even with training, they were not as capable as a faculty instructor would have been in engaging the student research teams in spontaneous follow-up interactions.

Ample data were collected on the number of clarifying interactions by topic and subtopic. Comparison of the mean values of the clarifying interaction rates for the two treatment groups during equivalent treatment weeks indicates that there were no significant differences in total clarifying interactions or in primary topics of clarifying interactions. This lends support to the comparability of the two treatment groups; when students were instructed using the same methods data show that the numbers, types and topics of interactions were not significantly different.

During the contrasting treatment block, a t-test indicates that the mean number of clarifying interactions for the student research teams was significantly higher for the lecture treatment group than for the podcast treatment group. Cohen’s $d$ is a standard measure of effect size and the calculated Cohen’s $d$ comparing the mean clarifying interaction rates for the treatment groups is 2.18. (A value of 0.8 or higher is considered a large effect.)

When these data were divided into interactions that centered on the preliminary inquiry activity (Q interactions), interactions that focused on planning and performing the experiment (E interactions), and interactions about data processing and drawing conclusions (P interactions), t-tests show that only the mean number of E interactions were significantly higher for the lecture treatment group. The calculated Cohen’s $d$ comparing the E interactions for the two treatment groups is 1.73; this would be considered a large effect size.

E interactions occurred during the planning and implementation of the experiment. During the experiment portion of the laboratory, students were required to make multiple
independent decisions. A primary goal of providing information in a podcast format to be accessed as needed was to allow students to work more independently. A reduction in the number of clarifying interactions during the experiment may reflect an increase in student independence.

Data on the subtopics of clarifying interactions were also collected and reported. Inter-rater reliability studies were not as strong for the collection of these subtopics so statistical analysis was limited. There were a few general trends that can be noted. First, the distribution of subtopics within the data sets for the two treatment groups was similar. Within the Q interaction category, more Q2 interactions that centered on ideological issues during the inquiry activity were recorded for both treatment groups. This is consistent with the often observed phenomenon that students can learn algorithmically to number crunch but may still struggle with concepts (Herron & Greenbowe, 1986; Nurrenbern & Pickering, 1987).

The E subtopic most frequently recorded for both groups was a category E4 interaction that represented interactions centering on the investigative procedure during the experiment. This subtopic was also the most frequent topic of interaction among all of the recorded interaction data. The large number of E4 interactions may reflect the lack of hands-on laboratory experience common among entry-level chemistry students. Finally, among the P topic categories, P7 interactions were recorded across the data collection window, but very few P8 interactions were recorded for either treatment group. Not surprisingly, most students seemed to be focused on completing the required claims and evidences portion of their laboratory reports, rather than pursuing connections with previous knowledge.
In summary, two types of scaffolding interactions were recorded during this study: clarifying interactions and follow-up interactions. Since the volume of data on follow-up interactions was quite small, data analysis was focused on the number and topics of clarifying interactions. Differences were evident in the numbers of clarifying interactions observed for the two treatment groups during the contrasting treatment block. A Welch’s t-test indicates that the student research teams who were part of the lecture treatment groups had a statistically significant higher rate of clarifying interaction with instructors than student research teams that were part of the podcast treatment group. More careful analysis of interaction data divided by topics shows that only the E interactions, or interactions focused on the experiment, show a statistically significant difference. When inspecting data on the sub-topics of all recorded interactions, the interactions coded as E4 interactions were the most frequently recorded and the subtopic that showed the greatest difference in means for the two treatment groups.

All of the podcasts that student research teams accessed except for the podcast covering simple statistics addressed topics that would directly influence the investigative procedure. Given the statistically significant difference in type E interactions, it might be reasonably concluded that the availability of the podcasts provided more support for students as they planned and performed their experiments than a traditional pre-laboratory lecture.

Third Research Question: Comparison of Student Outcome Measures

Data Analysis

The focus of the third research question was the student outcome measures of laboratory report grade average, laboratory quiz average, laboratory final exam grade and laboratory course average and any performance differences between students who had access
to the on-demand podcasts versus students who received the same information in a traditional lecture format. These outcome measures were collected from the database of grades for each laboratory section. Table 14 gives the overall mean values with standard deviation for each outcome measure listed by treatment group. The data were also compiled by gender, observed motivation level, and student classification for each treatment group. For the purposes of data analysis the factor of student classification was divided into two levels: freshmen students and non-freshman students that included sophomore, junior and senior students.

A Welch’s t-test comparing the overall report average data for the podcast treatment group and lecture treatment group indicate that the mean values were not significantly different ($t = -0.96$, $df = 117.53$, $p = .34$). Likewise, the overall mean quiz averages for the two treatment groups were not significantly different as judged by a Welch’s t-test ($t = -1.41$, $df = 104.19$, $p = .16$). Overall final exam grades can also be compared using a Welch’s t-test and the result indicates that scores for the two treatment groups were not significantly different ($t = .38$, $df = 119.34$, $p = .71$). The overall course averages were not significantly different as compared by a Welch’s t-test ($t = -.91$, $df = 119.89$, $p = .36$).

Analysis of variance (ANOVA) allows comparison of data by factors with two or more levels. Using this technique the data for students of different genders, observed motivation ratings, and classifications can be compared to see if there were differences in the mean values of their outcome measures that were dependent on treatment group. Interaction effects between these three factors for students in the podcast treatment and lecture treatment groups were investigated using a four-way ANOVA where the fourth way was treatment group.
### Table 14

**Mean Values for Student Outcome Measures by Treatment Groups**

<table>
<thead>
<tr>
<th>Outcome measures</th>
<th>Podcast treatment</th>
<th>Lecture treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \bar{X} )</td>
<td>SD</td>
</tr>
<tr>
<td>Report average</td>
<td></td>
<td></td>
</tr>
<tr>
<td>overall</td>
<td>91.6</td>
<td>6.74</td>
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<td>female</td>
<td>92.82</td>
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<td>male</td>
<td>90.16</td>
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<tr>
<td>high motivation</td>
<td>95.99</td>
<td>2.74</td>
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<td>middle motivation</td>
<td>89.78</td>
<td>6.93</td>
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<tr>
<td>low motivation</td>
<td>86.31</td>
<td>7.02</td>
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<td>freshmen</td>
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<td>7.27</td>
</tr>
<tr>
<td>non-freshmen</td>
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<td>7.27</td>
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<tr>
<td>Quiz Average</td>
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<td></td>
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<tr>
<td>overall</td>
<td>78.79</td>
<td>11.49</td>
</tr>
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<td>female</td>
<td>78.87</td>
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<td>10.70</td>
</tr>
<tr>
<td>high motivation</td>
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</tr>
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<td>middle motivation</td>
<td>75.22</td>
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<td>low motivation</td>
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<td>freshmen</td>
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<tr>
<td>non-freshmen</td>
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<td>Final Exam</td>
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<td>non-freshmen</td>
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<tr>
<td>Course average</td>
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<td>female</td>
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<td>7.55</td>
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<tr>
<td>non-freshmen</td>
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</tr>
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</table>

\*These values are statistically significantly different at the \( \alpha = .05 \) level.
Analysis of variance (ANOVA) allows comparison of data by factors with two or more levels. Using this technique the data for students of different genders, observed motivation ratings, and classifications can be compared to see if there were differences in the mean values of their outcome measures that were dependent on treatment group. Interaction effects between these three factors for students in the podcast treatment and lecture treatment groups were investigated using a four-way ANOVA where the fourth way was treatment group. This may reveal whether the mean value of an outcome measure for a student in one level of a factor was dependent on the level of another factor.

There were no statistically significant differences between outcome performances of male students participating in different treatment groups or female students participating in different treatment groups. Likewise, there were no significant differences between the mean values of each outcome measure for students who were classified as freshmen but were in different treatment groups or students who were non-freshmen and were in different treatment groups. Mean outcome measures for students exhibiting mid-range motivation or low motivation who were part of the podcast treatment group were not statistically significantly different than those in the same motivation category who were part of the lecture treatment group. The ANOVA for the overall course average using the four factors of gender, treatment group, classification and observed motivation did indicate an interaction effect between observed motivation and treatment group ($F = 6.032, p = .0033$); the Tukey post-hoc test revealed that the mean overall course grade for highly motivated students was significantly higher for those participating in the podcast treatment group. No other post-hoc contrasts
between mean outcome measure values for students of the same factor levels in different treatment groups were statistically significantly different.

Discussion

The statistical analysis of the data for all outcome measures indicates that as cohorts, students who were participants in the podcast treatment group and lecture treatment group performed at the same levels. The mean values of laboratory report grade average, laboratory quiz average, laboratory final exam grade and laboratory course average were not statistically significantly different for the two treatment groups. The instructors worked hard to ensure that students in all sections had the information and support that they needed to be successful in the coursework and the results of the data analysis indicate that the average performance for students in the sample was not affected by the treatments.

Factor analysis indicates that the only evident statistically significant difference was an interaction effect between observed motivation behavior and treatment group. Data from this study show that the mean value of the overall course grade for students who exhibited high motivation was significantly higher for those students who were part of the podcast treatment group than for students who exhibited high motivation who were part of the lecture treatment group. Since accessing podcasts requires personal initiative, it is not surprising that students who were more highly motivated might gain more from available podcasts due to greater persistent in accessing the podcasts and in being more attentive to their content. The availability of the podcasts provided all students additional opportunities to learn and highly motivated students may have benefitted more. Some caution is warranted in interpretation of this result. There were 33 students classified as highly motivated in the podcast treatment
group and 20 students in this category in the lecture treatment group. Additional studies examining larger samples are needed to verify this observed interaction effect.

Summary: Results in context

In addition to the quantitative data collected for this study, I collected qualitative data in the form of field notes. The student participants completed a typical end-of-course survey that included one Likert scale question that addressed the helpfulness of the podcasts and included a free response section that provided additional background data. These qualitative data are useful in placing the results of the conducted investigations into context.

The first research question addressed the extent to which student research teams used pertinent chemistry podcasts available as an on-demand resource. The podcasts replaced a traditional pre-laboratory lecture in four out of six sections of general chemistry laboratory during the contrasting treatment block. The results of the data analysis indicate that the podcasts were accessed on a regular basis throughout the data collection period. The extent of usage varied by week and by podcast. The variation in access rates may have been influenced by the variety of podcast topics, the variety of the experiments being performed and the differences in student preparation. Podcasts that addressed topics of calculations or concepts were accessed most extensively. For podcasts that were accessed during more than one week, the rates of usage decreased through the progression of the semester as students gained laboratory experience.

One concern for instructors using a new form of technology in any course is whether the technology itself will be an obstacle to student learning. ACU had begun deployment of iPhones® or iPod touches® as an academic support tool to all entering freshmen during the
academic year before data were collected for this study. The majority of students in the study sample were freshmen that had just received their devices. As the semester began instructors frequently tutored freshmen students in device manipulations, but they quickly became adept at finding and accessing the podcasts used in this study.

Though they had no difficulty accessing the podcasts, students were not accustomed to seeking information in this format during a class period and a few seemed resistant to using a resource that was not written. During the first few weeks before data collection began, the instructors regularly reminded student research teams that the podcasts were available and that they should use these resources as a first step in gathering information during the laboratory. Developing a culture of independence and of reliance on available resources was essential. As the semester progressed, students were given information on pertinent podcasts for the week’s experiment at the beginning of the laboratory period and student research teams were occasionally reminded of podcasts they could use when they asked questions covered by podcasts.

End-of-course evaluations indicated that students felt the podcasts were helpful. A 5-point Likert scale question on the course evaluation asked students to respond to the statement “I found the chemistry laboratory podcasts helpful”. The mean value for the Likert scale response for the 81 students in the podcast treatment group was 4.10 where a value of 5 represents strongly agree and 1 represents strongly disagree. Student comments in the free response section of the course evaluation included some comments about podcast usage including requests for additional podcasts and several suggestions that the podcasts be made available outside of the laboratory period so that students could use them before or after the
course meeting time. One student felt that some of the information in the podcasts was not clear and one student commented that it was difficult to focus on the podcasts in the noisy laboratory and suggested that the class watch the podcasts as a group before going in to the laboratory room.

The second research question addressed what differences might be evident in the number, types, and topics of scaffolding interactions between student research teams and instructors in lab sections that have access to on-demand podcasts but no pre-laboratory lecture and those who have been instructed using a traditional pre-laboratory lecture. The instructors recorded and categorized every scaffolding interaction using the SICS for all laboratory sessions during the data collection window. The ratio of clarifying interactions to follow-up interactions was 15:1. Due to the dearth of data on follow-up interactions, data analysis focused on the clarifying interactions. The analysis indicates that the student research teams in the podcast treatment group had significantly fewer clarifying interactions with an instructor than student research teams in the lecture treatment group during the contrasting treatment block. Using Cohen’s $d$ as an expression of effect size, the observed effect size was 2.18; this is considered a very large effect size. The mean numbers of clarifying interactions were not statistically significantly different for the two treatment groups during the weeks included in the equivalent treatment block. This supports the conclusion that the observed differences during the contrasting treatment block were the result of the differential treatments.

By topic, interactions centering on the planning and implementation of the experiment (E interactions) were most common comprising 66% of all interactions. Interactions focused on
the inquiry worksheet (Q interactions) made up 25% of the total clarifying interactions and the remaining 9% were interactions focused on data processing and connecting with previous knowledge (P interactions). Statistical analysis using the topical factors indicates that number of Q and P interactions were not statistically significantly different for the two treatment groups, however the number of E interactions was statistically significantly different. Since the topics covered in all of the podcasts except for the podcast “Simple Statistics” were applicable to the experimental portion of the laboratory, this result is not surprising.

The results of the first two research questions indicate that students used podcasts as a resource and that their use resulted in a decrease in the number of clarifying interactions between instructors and student research teams. While it is tempting to try to find a correlation between level of inquiry in a particular planned experiment, extent of podcast usage during the experiment, and numbers, types and topics of clarifying interactions during the experiment, such comparisons run the risk of incorporating an unwieldy number of confounding variables. Experiments might be compared by level of inquiry, but there is such great variety in the types of experiments conducted from week to week that such comparisons do not help define the extent to which students would be expected to seek assistance in the form of clarifying interactions or in podcast access events. The great variation in student background experience also complicates attempts to compare data from week to week, as does the variation in the difficulty of required laboratory techniques.

However, variety is a strength of this study. Despite the fact that the data were collected across multiple experiment types using six different sections with six different teaching assistants, data analysis shows a consistent trend. Student research teams used the
podcasts frequently. The number of clarifying interactions recorded for research teams that had podcast access where statistically significantly fewer than the number for research teams who did not have podcast access. At times, I observed an obvious difference in the academic atmosphere between sections in the podcast treatment group and lecture treatment groups. In particular, during the week that students used titration, the atmosphere was almost frantic during the lecture treatment sections. Though the students had listened to a pre-laboratory lecture describing the technique and saw physical demonstrations of the titration set-up, they were not confident about using the technique and the instructors were overwhelmed by questions. Student research teams still asked questions in the podcast treatment sections, but the atmosphere was much calmer; students watched the podcast on titration and seemed more comfortable with attempting to use this unfamiliar technique when the podcast was available for support.

There were three components to this study: the extent of podcast usage as a scaffolding support during inquiry based experiments, observation of interactions between student research teams and instructors during the laboratory sessions with podcast access and with lecture presentation, and the outcome measures for students in the two treatment groups. The third research question focused on the differences that might be observed in student outcome measures. The results of data analysis indicate that there were not statistically significant differences in the mean group laboratory averages, mean quiz averages, mean final exam grades, or mean course averages for students in the two treatment groups. There was one statistically significant interaction effect: students who were classified by the lecture instructors
as highly motivated and were part of the podcast treatment group had a significantly higher mean course average than the highly motivated students in the lecture treatment group.

The results of this study indicate that when pertinent chemistry laboratory podcasts were made available for students to access on demand as an alternative to a traditional pre-laboratory lecture, student research teams consistently accessed them. The number of interactions between instructors and student research team were significantly fewer in the sections that were given podcast access. Students who used podcasts as an alternative to the laboratory lecture performed at the same level on graded assignments as students who received a lecture. These results are an affirmation that podcasts are a viable option as a support for students in general chemistry laboratories and may be a resource that compliments the scaffolding support provided by instructors.
CHAPTER V

CONCLUSION

The National Research Council has identified inquiry-based instruction as a central approach for teaching science in the laboratory (Olson & Loucks-Horsley, 2000) and the American Chemical Society recognizes inquiry-based instruction as a pedagogy that “promotes independent thinking, critical thinking and reasoning, and a perspective of chemistry as a scientific process of discovery” (American Chemical Society, 2008, p. 9). However, inquiry-based laboratories that place responsibility on the students to generate procedures and design experiments can be a challenge to implement. Much discussion has been focused on the success of implementation and some studies indicate that inquiry-based instruction can be detrimental to student learning if students are not provided necessary support (Berg et al., 2003; Kirschner et al., 2006). Students must be adequately prepared in order to gain the benefits from increased student independence that results in discovery and enhanced conceptual understanding (Bruck & Towns, 2009).

Instructors in a laboratory taught with an inquiry-based curriculum provide expert modeling of techniques and cognitive processes before the laboratory activities begin and then move through the student laboratory groups providing assistance that may be described as scaffolding interaction. During these interactions they provide additional guidance as students move through understanding conceptual materials, use new laboratory techniques, and design experiments. Students in an introductory university level course come with a wide variety of high school science experiences; some have done extensive laboratory work, but most have had very limited exposure to using laboratory equipment or designing experiments. The novice
status of many students can make it very challenging for a single instructor to provide the
needed support for the 25-30 students typically enrolled in a general chemistry laboratory
section.

The cognitive apprenticeship theory provides a theoretical framework for understanding
how training can occur in a chemistry laboratory (Collins et al., 1991; Collins et al., 1989;
Lagowski & Stewart, 2003). This theory compares academic training to a traditional trade
apprenticeship and identifies six methods that are central to teaching and learning (Collins et
al., 1991; Collins et al., 1989). The first three methods are modeling, coaching and scaffolding
and assume frequent interaction between the instructor and student (Edmondson, 2005). In a
teaching laboratory with a high instructor to student ratio, technology can provide a platform
for expert modeling and if it is available during the laboratory sessions, the model provided via
technology can also act as a scaffold as students work in the laboratory (Collins, 1991). Thus the
technology support makes the cognitive apprenticeship of students in a teaching laboratory a
more accessible teaching model.

One technology that may be helpful in providing information for support of students in
a teaching laboratory is a handheld device such as an iPhone® or iPod touch® that delivers
video podcasts. Podcasts covering essential laboratory techniques and central concepts that aid
in experimental design or data processing can be made available for students to access on an
as-needed basis during laboratory sessions. This may provide individualized scaffolding support
as students select resources that cover topics they need to review. It may also free the
instructor during laboratory sessions to focus on assisting students with less routine concerns
and give the students the opportunity to work more independently.
The purpose of this study was to investigate the use of podcasts delivered on-demand as a scaffolding support to student research teams working in a laboratory taught with an inquiry-based curriculum. Students in six general chemistry laboratory sections were the sample used for the study. The same faculty instructor led all sections using the same inquiry-based curriculum. All students in the laboratory sections were enrolled in a general chemistry lecture course and each lecture course followed the same lecture schedule and gave common exams. Four sections were designated as the podcast treatment group and were granted access to podcasts prepared to support the curriculum. Two sections were designated as the lecture treatment group and did not have podcast access, but received analogous information support through a traditional pre-laboratory lecture. Treatment group cross-contamination was limited by restricting podcast availability to the university login accounts of students enrolled in the podcast treatment group sections during their assigned four-hour laboratory session. Podcasts were not available outside of the class meeting time.

The three research questions were investigated. The first research question focused on extent of podcast usage: when relevant chemistry podcasts are available for on-demand access during a general chemistry laboratory taught with an inquiry-based curriculum, how frequently will student research teams access them? This question was addressed using data collected from podcast access logs that allowed examination of the extent to which student research teams in the podcast treatment group would voluntarily access pertinent podcasts. The number of access events was determined from the access logs, and data analysis indicates that the research teams studied for this investigation did use the podcasts regularly during the data collection window. On average, each student research team accessed a podcast 2.86 times
during each week that podcasts were available. The topics of the podcasts varied widely and the number of access events for particular podcasts also varied widely. The variation in usage is attributable to the familiarity of the podcast topics, the number of experiments for which a podcast to might be useful, and the complexity of the topic covered by a podcast. Podcasts that described conceptual materials were the most frequently accessed files, with mean weekly access rates in the range 2.21-2.63 access events per research team. Podcasts that described laboratory techniques were accessed less frequently and had mean weekly access rates in the range of 0.45-1.88 access events per research team.

The second research question focused on interactions between instructors and students in the laboratory setting: what differences are evident in the number, types, and topics of scaffolding interactions between student research teams and instructors in lab sections that have access to on-demand podcasts but no pre-laboratory lecture and those who have been instructed using traditional pre-laboratory lectures? To explore the second research question, data were collected on the numbers, types, and topics of scaffolding interactions between student research teams and instructors. The SICS (Scaffolding Interaction Categorization Scheme) was developed in preparation for this study and was used as a data collection instrument. Comparison of interaction data for the student research teams that were part of the lecture treatment group and the teams that were part of the podcast treatment group give insight into the comparable effectiveness of podcast delivery of information versus traditional lecture delivery of information. The materials presented in the lectures and the podcasts were closely aligned and delivered by the same instructor. During weeks when the treatment groups received the contrasting treatments, the number of clarifying interactions for the podcast
treatment group was statistically significantly lower than that for the lecture treatment group. Analysis by topics reveals that the student research team interactions with instructors that focused on the planning and implementation of the experiments were the only topic of interactions that were statistically significantly different. The podcasts that were accessed during the data collection window centered on topics that would be applicable to the experiment phase of the laboratory sessions with one exception: “Simple Statistics.”

The implication of the results of interaction data analysis is that student research teams that were part of this study were able to gather laboratory information more effectively when it was presented in an on-demand podcast format, than when it was presented in a traditional lecture format. These results might be explained by referencing Bandura’s theory of modeling that suggests important requirements for successful modeling are access to essential information, the ability to retain (or perhaps re-access) that information and student attentiveness (Bandura, 1997). Availability of podcasts may offer advantages over a pre-laboratory lecture as a modeling format in several ways: (1) students are able to listen to the podcasts repeatedly if they do not understand the presentation during the first access, (2) students may be able to focus more intently on a podcast that they control on a handheld device rather than on a lecture delivered from the front of a classroom, (3) podcasts on a wide range of topics can be made available for students with varying background preparation, and (4) students may be better prepared to hear and understand information when they are at the point of needing to make decisions in the laboratory that depend on that information.

Podcasts were used frequently and seem to be an effective tool for delivery of pertinent chemistry information for students working in the laboratory, but did the delivery method
affect student outcome measures? The third research question focused on any evident differences in student performance between the two treatment groups: what do the student outcome measures of laboratory report grade average, laboratory quiz average, laboratory final exam grade and laboratory course average indicate about performance differences between students who have access to the on-demand podcasts versus students who have received the same information in a traditional lecture format? The mean values of laboratory report average, the mean values of quiz average, the mean values of final exam grade, and the mean value of course average were compared for the two treatment groups. Statistical analysis indicates no significant differences between outcome measures for the treatment groups when compared as cohorts. Comparison by factors of student classification and gender, low motivation and mid-range motivation also show no significant differences in the outcome measures between students in the podcast treatment and lecture treatment groups. The only statistically significant difference is between students judged to be highly motivated; for this sub-group the students in the podcast treatment group earned a course average that was statistically significantly higher than those in the lecture treatment group. Accessing a podcast does require personal initiative; it is not a passive activity. Highly motivated students might be more likely to benefit from the availability of the podcast resources by virtue of their higher desire to achieve.

This research study provides some of the first data collected on the effectiveness of podcasts delivered as needed in a laboratory setting. The results provide insight into how often student research teams accessed the pertinent podcasts and how use of podcasts compared with a traditional pre-laboratory lecture as a support for students in an inquiry-based
laboratory setting. The data collected on student interactions with instructors during laboratory sessions and data collected on student outcome measures indicate that student participants were able to work more independently when they had podcast access and that their performance on outcome measures was at least equivalent to that of students who received a pre-laboratory lecture.

Limitations of the Study

Data for this study were collected in a first-semester general chemistry laboratory course taught at a small private university. The results of this study cannot be generalized to all general chemistry laboratory courses because the curriculum used in the sample classrooms was locally prepared and adapted to fit the laboratory schedule and format used at ACU. The same instructor led the six general chemistry laboratory sections that were part of this study. While the uniformity of the instruction style and curriculum limits confounding variables and is advantageous for providing a stable environment for data collection, it also limits the validity of extending the results to other laboratory settings.

Suggestions for Future Research

Additional research projects in multiple general chemistry programs or within larger university programs that employ multiple faculty instructors and graduate teaching assistants will be a next important step in investigating the effectiveness of podcasts delivered in a laboratory setting. Comparison of data collected during laboratory sessions taught at different universities using uniform written curriculum and data collection methodologies would allow a broader view of podcast effectiveness. The same types of research questions that have been addressed using our narrower sample should be addressed with this larger group. When
relevant chemistry podcasts are available for on-demand access, how frequently will student research teams access them? What differences are evident in the number, types, and topics of scaffolding interactions between student research teams and instructors in lab sections that have access to on-demand podcasts but no pre-laboratory lecture and those who have been instructed using a traditional pre-laboratory lecture? What do the student outcome measures indicate about performance differences between students who have access to the on-demand podcasts versus students who have received the same information in a traditional lecture format?

A standard measure of laboratory student performance would provide a basis for comparison of the laboratory learning of students in different general chemistry programs who used podcasts and who received a traditional laboratory lecture. An ACS standardized test for general chemistry laboratory that is nationally normalized is in development. Use of this tool would allow comparison of students prepared for laboratory work using podcasts and using traditional pre-laboratory lecture. What differences in performance between students who access laboratory podcasts and students who receive information in lecture format are evident as judged by a standardized laboratory test? Factor analysis of student performance by question topics on the standardized test may help identify strengths and weaknesses of podcast usage and lecture presentation. What types of information and skills are most effectively presented by podcast delivery as judged by student performance on a standardized laboratory test?

Helpful insight might be gained by research studies that include observation of students performing laboratory tasks and student descriptions of laboratory protocol. Using very
detailed evaluation rubrics, investigators could compare performance and understanding of laboratory skills. What differences are evident in student performance of laboratory skills between students who learn a laboratory technique via lecture presentation and students who learn the same technique via podcast presentation? What differences are evident in student conceptual understanding of laboratory procedures and techniques between students who learn about a laboratory procedures and technique via lecture presentation and students who learn the same information via podcast presentation?

Finally, studies on the effectiveness of podcasts prepared for student support during both introductory laboratory courses and upper division chemistry laboratory courses will be important in developing a strong research-based pedagogy for incorporating mobile devices in the chemistry laboratory setting. This study focused on very basic laboratory techniques and concepts used in an introductory-level teaching laboratory. Podcasts are being developed for use in upper division courses (Anderson & Yocom, 2009; Yocom & Anderson, 2009). Anecdotal evidence suggests that podcasts delivered on a mobile platform are effectively used to teach more complex procedures and techniques than those presented in the podcasts prepared for this study. What differences are evident in student conceptual understanding of complex laboratory procedures and techniques between students who learn about laboratory procedures and technique via lecture presentation and students who learn the same information via podcast presentation? Can podcasts be used as a leveling tool for students who are taught by TAs with different background preparations?

Portable devices that are capable of delivering podcasts on demand are a newer technology, but the number of university enrolled individuals that own a device is escalating.
Within five years it is likely that a large majority of students will own a device capable of delivering podcasts that also provide ready access to Internet resources (Smith et al., 2009). Podcasts and other technology-based resources are commonly utilized in chemistry curriculum as a pre-laboratory preparatory tool. Handheld smartphones such as the iPhone® offer seemingly limitless opportunities to develop applications that may allow data collection with attached probes, data processing, course content delivery and student assessment in addition to video recording, photography, and easy communication between students and instructors. As mobile technology advances it seems likely merged devices that can be very easily taken “in to the field” will have a huge impact on the way teaching and learning is envisioned. Creative use of technology may open doors to new and better teaching and learning in the chemistry laboratory. Mobile devices are changing our society; it is important to learn how we might harness their capabilities to enhance chemistry education.
APPENDIX A

IRB APPROVALS AND STUDENT RELEASE FORM
September 2, 2008

Cynthia Powell
Department of Chemistry
University of North Texas

Re: Human Subjects Application No. 08277

Dear Ms. Powell:

As permitted by federal law and regulations governing the use of human subjects in research projects (45 CFR 46), the UNT Institutional Review Board has reviewed your proposed project titled “Using iPhones to Support Student Success for Inquiry Based General Chemistry Laboratories.” The risks inherent in this research are minimal, and the potential benefits to the subject outweigh those risks. The submitted protocol is hereby approved for the use of human subjects in this study. Federal Policy 45 CFR 46.109(e) stipulates that IRB approval is for one year only, September 2, 2008 to September 1, 2009.

It is your responsibility according to U.S. Department of Health and Human Services regulations to submit annual and terminal progress reports to the IRB for this project. Please mark your calendar accordingly. The IRB must also review this project prior to any modifications.

Please contact Shelia Bourns, Research Compliance Administrator, or Boyd Herndon, Director of Research Compliance, at extension 3940, if you wish to make changes or need additional information.

Sincerely,

Patricia L. Kaminski, Ph.D.
Chair
Institutional Review Board

PK: sb

CC: Dr. Diana Mason
September 2, 2008

Cynthia Powell
Department of Chemistry
University of North Texas

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Please contact Sheila Bourns, Research Compliance Administrator, or Boyd Herndon, Director of Research Compliance, at extension 3940, if you wish to make changes or need additional information.

Sincerely,

[Signature]

Patricia L. Kuminiski, Ph.D.
Chair
Institutional Review Board

PK: sb

CC: Dr. Diana Mason
August 8, 2008

Cynthia Powell
Department of Chemistry and Biochemistry
Foster Science Building
Abilene Christian University
Abilene, TX 79699-8011

Cynthia,

On behalf of the Institutional Review Board I have approved your project titled The Use of iPhones/iPod Touches to Support Guided Inquiry Chemistry Laboratories. You are now approved for data collection and analyses. Please notify this office when you have completed your study. Should any problems develop with the study, please inform the Office of Research promptly.

I wish you well with your work.

Sincerely,

Scott Perkins, Ph.D.
Director of Research
Office of Research and Sponsored Programs
Chemistry Education Study Informed Consent Form

As educators and researchers we are always interested in improving our student’s educational experiences and successes. We will be introducing the use of iPhones/iPod touches as a learning tool in some of our courses. We are particularly interested in advantages or disadvantages of their use and in how students use them during independent laboratory work sessions. All sections, whether they are “iPhone/iPod” sections or not will have access to the same on line tools. The only difference between the sections will be the availability of these tools on the portable learning devices and some interactive uses of the devices during class time. We would like to determine whether the use of the iPhones/iPod touches to support guided inquiry labs and guided inquiry problem sessions provide an advantage to the students and instructors using them. We plan to determine the correlation between regular quizzes and grades earned in chemistry courses, student engagement in laboratory sessions, self-reported assessment of chemistry learning, and student evaluations and instructor evaluations. Demographic data such as gender, math and chemistry courses completed, entrance exam scores, hometown, major and intended career goal may be used to analyze data.

This informed consent form is a release form that will allow your data to be included in this study. You will not be asked to do any additional work that is not required for your chemistry course, but may be asked to complete short questionnaires giving information about your views on effectiveness of teaching methods and lab activities. All compiled information, both qualitative and quantitative, will be stored with a student code number; no names will be attached to any compiled information. Any published or presented information will be statistical in nature and individual student scores and responses will not be distinguishable.

Our intent is to use this information to improve the chemistry education program at ACU and to use collected data for the purposes of Education Research projects. The results of this study will probably not provide any direct benefit to you, but our hope is that it will benefit students in coming years. You will receive no monetary compensation for allowing your data to be used in this study. Any questions you have about this study may be directed to Mrs. Cynthia Powell, Abilene Christian University Department of Chemistry and Biochemistry, XXX-XXX-XXXX. Mrs. Powell is a graduate student at the University of North Texas therefore, this research study has also been reviewed and approved by the University of North Texas Institutional Review Board (IRB). The UNT IRB can be contacted at (940) 565-3940 with any questions regarding the rights of research subjects.

Your signature below indicates that you agree to allow your data to be used in this study and further indicates that:

1) you have read and understand the information above
2) you understand that releasing your data is voluntary and that your refusal will not result in a penalty of any kind
3) you understand that you are free to withdraw your data from inclusion in this study at any time

Participant: ________________________________  Date: ______________
APPENDIX B

LABORATORY ORGANIZATION AND CURRICULUM DOCUMENT
<table>
<thead>
<tr>
<th>Week</th>
<th>Laboratory title</th>
<th>Topics introduced</th>
<th>Chapter in Chemistry, 9th edition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>How “reliable” are the volume markings on beakers and graduated cylinders?</td>
<td>Measurement using glassware, accuracy and precision, significant figures, simple statistics (mean, outliers), electronic balances</td>
<td>Chapter 1: The Foundations of Chemistry</td>
</tr>
<tr>
<td>2</td>
<td>How can I know what compound is formed?</td>
<td>Stoichiometry, reaction between Mg and O₂, empirical formulas, use of crucibles</td>
<td>Chapter 2: Chemical Formulas and Composition Stoichiometry</td>
</tr>
<tr>
<td>3</td>
<td>How can we compare changes in pressure, volume, and temperature for a trapped gas sample?</td>
<td>Boyle’s law, relationship between volume and temperature of a gas sample, combined gas law, use of Vernier equipment and software</td>
<td>Chapter 12: Gases and the Kinetic Molecular Theory</td>
</tr>
<tr>
<td>4</td>
<td>Determining R. Will our value match the one we’ve memorized? Will we even get a constant?</td>
<td>Atmospheric pressure, use of stoichiometry to determine theoretical yield, gas collection apparatus, ideal gas law, simple statistics (standard deviation)</td>
<td>Chapter 12: Gases and the Kinetic Molecular Theory</td>
</tr>
<tr>
<td>5</td>
<td>The reaction between lead(II) nitrate and potassium iodide in aqueous solution ... what happens and how can you influence it?</td>
<td>Use of stoichiometry to determine theoretical yield, reaction conditions, limiting reagents, solubility, filtering and drying of a product, percent yield</td>
<td>Chapter 3: Chemical Equations and Reaction Stoichiometry</td>
</tr>
<tr>
<td>6</td>
<td>Identifying elements by a flame test. FIRE!!!</td>
<td>History of determination of the structure of the atom, atomic structure, absorption and emission spectra, qualitative analysis</td>
<td>Chapter 4: The Structure of the Atom</td>
</tr>
<tr>
<td>7</td>
<td>Using the Cambridge Crystallographic database to investigate atomic radii</td>
<td>Periodic trends</td>
<td>Chapter 5: Chemical Periodicity</td>
</tr>
<tr>
<td>8</td>
<td>Can we predict which metals will react?</td>
<td>Reactivity of various metals with water, steam, a non-oxidizing acid, and aqueous solutions salts of other metals, evidences of reactions</td>
<td>Chapter 6: Some Types of Chemical Reactions</td>
</tr>
<tr>
<td>9</td>
<td>Using titration to determine the neutralizing effects of antacids on HCl (stomach acid!)</td>
<td>Titration procedure, neutralization, acid-base reactions (metathesis)</td>
<td>Chapter 6: Some Types of Chemical Reactions</td>
</tr>
<tr>
<td>10</td>
<td>Making an alum from scrap aluminum and testing it as a flocculent</td>
<td>Types of bonding, techniques of chemical synthesis including vacuum filtration and crystallization, safe use of concentrated acids</td>
<td>Chapter 7: Chemical Bonding</td>
</tr>
<tr>
<td>11</td>
<td>Making soap and testing its ability to suspend dirt and oils in aqueous solution</td>
<td>Polarity and its effects on chemical behavior, saponification, properties of oils</td>
<td>Chapter 8: Molecular Structure and Covalent Bonding Theories</td>
</tr>
<tr>
<td>12</td>
<td>Using model kits to predict the structures of simple compounds</td>
<td>Lewis dot structures, VSEPR theory, determining polarity from structure, determining molecular shape from electron counts around a central atom</td>
<td>Chapter 8: Molecular Structure and Covalent Bonding Theories</td>
</tr>
</tbody>
</table>
# Table B.2

*Research Team Roles and Responsibilities for the Team Lab Report*

<table>
<thead>
<tr>
<th>Role title</th>
<th>Responsibilities during team activities</th>
<th>Responsible for drafting this portion of the team report</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manager</strong></td>
<td>The manager is the team leader and manages both supplies and people. In the lab they will retrieve all needed supplies for the research team. They are responsible for making sure that everyone is involved in the classroom or laboratory activity and everyone has the information and supplies needed. The manager will assign specific tasks to each group member when needed.</td>
<td>Group procedure summary and beginning questions</td>
</tr>
<tr>
<td><strong>Technician 1</strong></td>
<td>During classroom activities, Technician 1 is responsible for reading each question out loud as the group works through the guided study. This serves to keep everyone moving through the material together. In the lab, both of the technicians are responsible for collecting data. Technician 1 is also responsible for keeping up with significant figures and pulling up podcasts for viewing when needed.</td>
<td>Observations and Data sections</td>
</tr>
<tr>
<td><strong>Technician 2</strong></td>
<td>During both classroom and laboratory activities Technician 2 is the designated user of a calculator when calculations are needed. All students will need to record the correct method for calculating, so this individual must explain how they are completing calculations. In the lab, both of the technicians are responsible for collecting data.</td>
<td>Calculations and Graphs sections</td>
</tr>
<tr>
<td><strong>Spokesperson</strong></td>
<td>During both classroom and laboratory activities the spokesperson is the only person allowed to speak for a group (can approach neighboring groups, raise hand to seek instructor help, or may be called on by instructor).</td>
<td>Evidence and Analysis sections</td>
</tr>
</tbody>
</table>
Rubric for Grading the Team Lab Report (30 points total)

The portions in the bold dark box are to be completed in your laboratory notebook as a pre-laboratory exercise before coming to class. You will turn it in at the beginning of class and the TAs will check it for completion and return it before you move into the laboratory to work. The points earned on the pre-laboratory portion will count in your total team lab report grade.

<table>
<thead>
<tr>
<th>Notebook Section</th>
<th>Section Contents</th>
<th>Point value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual Procedure</td>
<td>(1) List of needed chemicals and laboratory equipment</td>
<td>4 pts</td>
</tr>
<tr>
<td></td>
<td>(2) Step-by-step summary of provided procedure in sentences.</td>
<td></td>
</tr>
<tr>
<td>Individual Questions</td>
<td>(1) Suggested “big” question to investigate</td>
<td>2 pts</td>
</tr>
<tr>
<td></td>
<td>(2) Two “smaller” questions to investigate</td>
<td></td>
</tr>
<tr>
<td>Safety and Waste</td>
<td>(1) What specific precautions should be taken in the procedure?</td>
<td>2 pts</td>
</tr>
<tr>
<td>Considerations</td>
<td>(Sentences!)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) How should waste disposal of the experimental chemicals be handled? (Are the</td>
<td></td>
</tr>
<tr>
<td></td>
<td>chemicals hazardous or non-hazardous?)</td>
<td></td>
</tr>
<tr>
<td>Team Procedure Summary</td>
<td>Summarize the steps actually performed during the team’s experiment.</td>
<td>4 pts</td>
</tr>
<tr>
<td></td>
<td>Specifically explain the modifications your group has used. (Sentences!)</td>
<td></td>
</tr>
<tr>
<td>Team Beginning Questions</td>
<td>(1) Whole class consensus on “big” question to investigate</td>
<td>2 pts</td>
</tr>
<tr>
<td></td>
<td>(2) Team consensus “smaller” questions to investigate (may not apply in every</td>
<td></td>
</tr>
<tr>
<td></td>
<td>week)</td>
<td></td>
</tr>
<tr>
<td>Team Observations and</td>
<td>(1) Qualitative observations</td>
<td>4 pts</td>
</tr>
<tr>
<td>Data</td>
<td>(2) Quantitative data (watch significant figures!)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) If the experiment involves a chemical reaction, include the balanced</td>
<td></td>
</tr>
<tr>
<td></td>
<td>chemical equation.</td>
<td></td>
</tr>
<tr>
<td>Team Calculations and</td>
<td>(1) Calculations used to process data. (Watch significant figures! If a type</td>
<td>4 pts</td>
</tr>
<tr>
<td>Graphs</td>
<td>of calculation is used repeatedly, show one detailed example.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) If a graph will help with data interpretation or in supporting team</td>
<td></td>
</tr>
<tr>
<td></td>
<td>claims include it in this section. Be sure that it is properly labeled and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>titled.</td>
<td></td>
</tr>
<tr>
<td>Team Claim(s)</td>
<td>Answer the beginning question(s) with a claim or claims expressed in full</td>
<td>2 pts</td>
</tr>
<tr>
<td></td>
<td>sentences.</td>
<td></td>
</tr>
<tr>
<td>Team Evidence and</td>
<td>(1) IN PARAGRAPH FORM, clearly describe the interpretation of data (graphs,</td>
<td>6 pts</td>
</tr>
<tr>
<td>Analysis</td>
<td>class data, calculations) to support the claim(s).</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2) Include any difficulties encountered in the experiment that may have</td>
<td></td>
</tr>
<tr>
<td></td>
<td>resulted in qualitative or quantitative consequences. Be specific!</td>
<td></td>
</tr>
</tbody>
</table>
Guidelines for Grading the Individual Reflection (15 points total)

4 pts  (1) How does this work tie into chemistry concepts studied in the lecture course?

4 pts  (2) What did you learn from this experiment? How have your ideas changed?

4 pts  (3) What further questions do you have related to this work?

3 pts  (4) What real life applications are connected with this laboratory work?

The reflection should be 200-350 words in length and should be written in paragraph form. One point per section will be deducted for misspellings or grammar mistakes that occur in the section response.
SAMPLE STUDENT LAB REPORT

Using Titration to Determine the Neutralizing Effects of Antacids on Stomach Acid

Procedure Summary:

1. Clean the pipet and buret.
   - Clean the buret with soap and water and rinse well.
   - Rinse the buret with the NaOH solution.
   - Rinse the pipet with the HCl solution.
2. Fill the buret with NaOH.
3. Fill the graduated pipet to the marking and empty into an Erlenmeyer flask.
4. Add indicator.
5. Titrate the solution, by slowly adding NaOH until color appears.
6. Calculate the molarity of the acid by using the amount of NaOH required to neutralize the acid.

Beginning Questions:

Big Question:
How do you find the molarity of an HCl of unknown molarity?

Small Question:
How does the amount of antacid affect the amount of NaOH required to neutralize the HCl?

Team Observations and Data:

Reaction: \( \text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O} \)

In Trial 1, 25 mL of the HCl solution labeled solution A was used. The HCl solution was then titrated with the NaOH solution. Once 24.93 mL of the NaOH solution was added to the HCl solution, the solution stayed a consistent shade of pink.

In Trial 2, using the same amount and type of HCl solution, 25.45 mL of NaOH solution was used to reach endpoint.

In Trial 3, 25 mL of the HCl solution labeled solution B was used. 19.35 mL of NaOH solution was used to completely titrate the solution.

In Trial 4, using the same amount and type of HCl solution, with the addition of .519 g of Tums, 15.82 mL of NaOH were used.

In Trial 5, .986 g of Tums were used, which required 13.12 mL of NaOH.

In Trial 6, 1.608 g of Tums were used, which required 8.93 mL of NaOH.
Data

<table>
<thead>
<tr>
<th></th>
<th>Solution</th>
<th>Initial Volume of HCl</th>
<th>Amount of Antacid (Tums)</th>
<th>Total Amount of NaOH used</th>
<th>Molarity of HCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trial 1</td>
<td>A</td>
<td>25 mL</td>
<td>---------------</td>
<td>24.93 mL</td>
<td>1.034 M</td>
</tr>
<tr>
<td>Trial 2</td>
<td>A</td>
<td>25 mL</td>
<td>---------------</td>
<td>25.45 mL</td>
<td>1.045 M</td>
</tr>
<tr>
<td>Trial 3</td>
<td>B</td>
<td>25 mL</td>
<td>---------------</td>
<td>19.35 mL</td>
<td>0.804 M</td>
</tr>
<tr>
<td>Trial 4</td>
<td>B</td>
<td>25 mL</td>
<td>.519 g</td>
<td>15.82 mL</td>
<td>0.656 M</td>
</tr>
<tr>
<td>Trial 5</td>
<td>B</td>
<td>25 mL</td>
<td>.986 g</td>
<td>13.12 mL</td>
<td>0.544 M</td>
</tr>
<tr>
<td>Trial 6</td>
<td>B</td>
<td>25 mL</td>
<td>1.608 g</td>
<td>8.93 mL</td>
<td>0.370 M</td>
</tr>
</tbody>
</table>

Team Graphs and Calculations:

Percent error (difference) of two Solution A titrations:

\[
\frac{(1.034+1.045)}{2} = 1.040
\]
\[
\frac{(1.040-1.040)}{1.040} = 0\% \text{ error}
\]

Molarity:

\[
\text{Amount of NaOH used (L) } \times \text{ Molarity of NaOH} = \text{ Moles NaOH}
\]
\[
\text{Moles NaOH} = \text{ Moles HCl}
\]
\[
\text{Moles HCl / L HCl} = \text{ Molarity of HCl}
\]

Therefore for the molarity of solution B:

\[
19.35 \text{ mL of NaOH / 1000 mL} = 0.01935 \text{ L}
\]
\[
0.01935 \text{ L} \times 1.037 \text{ M} = 0.02006 \text{ mol NaOH}
\]
\[
0.02006 \text{ mol NaOH} = 0.02006 \text{ mol HCl}
\]
\[
0.02006 \text{ mol HCl / 0.025 L HCl} = 0.8026 \text{ M}
\]
Team Claims, Evidence, and Analysis:

How do you find the molarity of an acid of unknown molarity?

Titrate an exact amount of HCl solution (analyte) containing 2 drops of phenolphthalein (indicator) with standard NaOH solution. You do this by adding drops of standard NaOH from a buret to the HCl solution while stirring until the solution reaches its endpoint. You will know the solution has reached its endpoint when the solution turns a light pink color and stays pink after swirling. You calculate the molarity by using the data you collect and the given concentration of the standard NaOH.

How does the amount of antacid affect the amount of NaOH to neutralize the acid?

The greater the amount of antacid added (Tums in our experiment), the less the amount of NaOH required to neutralize the HCl. From the graph it looks like it is a linear relationship. (See graph.) We only tested one of the antacids in different amounts, but the class data shows that Tums and Rolaids neutralized the acid at about the same levels, but Gaviscon didn’t make very much difference in the acid concentration at all. Also from the class data, we see that if the antacids are allowed to react longer, they neutralize a little bit more of the acid making the concentration of HCl lower even though the same amount of the same type of antacid was added. One group tested temperature to see if it mattered if the acid solution was warm when the antacid was added and this didn’t seem to make very much difference.

Problems:

We had a problem with adding the exact amount of NaOH to the HCl solution to get a light pink. In one experiment, we got a darker pink than we were supposed to, but we don’t think that the extra amount of NaOH should cause a significant error.
Lab 9 Reflection

In lab this week we learned about titration. In the experiment, we titrated HCl acidic solution with NaOH basic solution until the solution was neutralized. In lecture, we have been learning about acids and bases and have discussed the reactions that occur between them. However, we have not yet discussed the technique of titration in the lecture portion of this class.

From completing this experiment, I most importantly learned how to titrate a solution. I also learned how to find the moles of a solution used in the titration process, as well as the molarity of a solution. I felt as though this lab was fairly easy to complete and offered a lot of new and important information.

In our experiment, we used different amounts of the Tums antacid in solution B of HCl. After completing this lab, I would like to see what the outcome of the experiment would be if we used antacids, other than the ones used in our experiment, in different amounts. I would also like to experience the titration process using different acids and bases.

The information learned this week, as shown with the antacids, can be used in real-life situations in the pharmaceutical field. When medicines are being made for things such as stomachaches, to neutralize the acidity in the stomach, titration can be used to see what different amounts of solutions need to be used in the medicine to relieve the pain and neutralize the stomach acids.
A General Chemistry Lab student, Jane, is conducting an experiment during which she heats pure chromium wire in a crucible. The chromium reacts with oxygen in the atmosphere. Jane would like to determine what compound she has produced in the reaction. Her data for the experiment is listed below. Answer the following questions about the experiment.

**Mass of Crucible**: 27.8251 g  
**Mass of Crucible + Cr wire**: 28.2801 g  
**Mass of Crucible + reacted Cr wire**: 28.6999 g  
**Molar mass of Cr**: 52.00 g/mole  
**Molar mass of O**: 16.00 g/mole

1. Jane was very careful to heat the crucible and allow it to cool before placing the chromium wire in the crucible. Why is this procedure is recommended?

   (a) Moisture in the crucible will cause the empty crucible to have a higher mass than it would if it were dry.

   (b) The crucible needs to be pre-heated so that it won’t crack when used for the reaction.

   (c) Moisture in the empty crucible could cause the final product to appear to have a higher mass than its actual mass.

   (d) The chromium wire will not melt if the crucible isn’t heated first.

2. Initially, Jane’s chromium did not seem to be reacting; she could see no visible change. What adjustment could she make to try to encourage the reaction to occur?

   (a) She could add more chromium wire to the crucible.

   (b) She could check to make sure that the wire was tightly wrapped.

   (c) She could adjust the burner flame so that the inner blue cone was touching the bottom of the crucible.

   (d) She could remove the crucible lid and do the experiment without a lid.
(3) Calculate the number of grams of Cr and O that have reacted to produce the product in this experiment. Show your work below:

(4) Calculate the number of moles of Cr and moles of O that have reacted to produce the product in this experiment. Show your work below:

(5) Determine the mole ratio of Cr:O for the product in this reaction. Show your work below:

(6) Write the empirical formula for the Cr/O compound that was produced in Jane’s reaction.
General Chemistry Laboratory—Quiz

John is experimenting with samples of air in the laboratory. He has a syringe attached to a gas pressure sensor that he can use to determine the relationship between pressure of the sample and volume of the sample. He is able to immerse his syringe in a water bath to vary the temperature of the sample. In this experiment volume and temperature were the independent variables (the variables that were changed). Pressure was the dependent variable (the variable that changed in response to the independent variable movement).

<table>
<thead>
<tr>
<th>Volume (mL)</th>
<th>Pressure (atm)</th>
<th>Temperature (K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>2.99</td>
<td>298.0</td>
</tr>
<tr>
<td>7.5</td>
<td>0.997</td>
<td>298.0</td>
</tr>
<tr>
<td>12.5</td>
<td>0.598</td>
<td>298.0</td>
</tr>
<tr>
<td>2.5</td>
<td>2.74</td>
<td>273.0</td>
</tr>
<tr>
<td>7.5</td>
<td>0.913</td>
<td>273.0</td>
</tr>
<tr>
<td>12.5</td>
<td>0.548</td>
<td>273.0</td>
</tr>
<tr>
<td>2.5</td>
<td>3.49</td>
<td>348.0</td>
</tr>
<tr>
<td>7.5</td>
<td>1.16</td>
<td>348.0</td>
</tr>
<tr>
<td>12.5</td>
<td>0.699</td>
<td>348.0</td>
</tr>
</tbody>
</table>

Question #1- Pressure and Volume (temperature constant)

(a) Does this data indicate that the relationship between volume and pressure is a direct relationship or an inverse relationship? (Hint: look at the data corresponding to a single temperature.) Explain how you decided.

(b) Using the data for volume and pressure calculate the value of k at 298.0 K. Show your work below.

(c) Is the value of k the same at each temperature? (Support your answer with evidence!)
Question #2- Pressure and Temperature (volume constant)

(a) Does this data indicate that the relationship between temperature and pressure is a direct relationship or an inverse relationship? (Hint: look at the data corresponding to a single volume.) Explain how you decided.

(b) Using the data for pressure and temperature calculate the value of k at a volume of 7.5 mL. Show your work below.

(c) Is the value of k the same for each volume? (Support your answer with evidence!)

Question #3- Using your lab notes!

In the lab conducted last week, we reacted Mg metal with oxygen gas in the atmosphere. How did you determine the amount of oxygen used in the reaction?

(a) weighed the amount of Mg/O compound in the final product and the amount of Mg metal in the final product and took the difference in weights

(b) weighed the amount of Mg/O compound and the amount of Mg metal that you started with and took the difference in weights

(c) determined the mole ratio of Mg:O in the final compound and calculated how much oxygen would be required

(d) determined the gram ratio of Mg:O in the final compound which allowed you to determine the oxygen used
General Chemistry Laboratory—Quiz

Name: ________________________________

Question #1
Susan is collecting samples of H₂ gas from the reaction between hydrochloric acid and zinc metal. The balanced equation for the reaction is shown below:

\[ \text{Zn}(s) + 2\text{HCl}(l) \rightarrow \text{ZnCl}_2(aq) + \text{H}_2(g) \]

The HCl concentration is 0.75 moles per liter of solution. Susan added 4.25 mL of the acid to zinc to start the reaction and collected the gas. There is plenty of zinc, so all of the HCl will react. How many moles of HCl has Susan used in the reaction? (Show your work.)

How many moles of H₂(g) should Susan be able to collect from the reaction? (Explain and/or show your work!)

Given the following data, calculate the value of R for Susan’s reaction. (There are some values you may need on the back of this page)

Volume of gas collected = 36.4 mL
Atmospheric Pressure = 752.00 torr
Temperature = 24.0 °C

Show your work!

Given an expected value of .08206 L·atm/K·mol for “R”, what is Susan’s percent error?
Question #2- Using your lab notes!

A Mohr pipet is a pipet that:
(a) allows you to deliver more liquid than other pipets.
(b) can only deliver exactly 10 mL of liquid.
(c) has a baseline mark.
(d) does not have a baseline mark; the numbering continues toward the pipet tip.

Vapor Pressure of Water Near Room Temperature:

<table>
<thead>
<tr>
<th>°C</th>
<th>Vapor Pressure of Water (torr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>19.83</td>
</tr>
<tr>
<td>23</td>
<td>21.07</td>
</tr>
<tr>
<td>24</td>
<td>22.38</td>
</tr>
<tr>
<td>25</td>
<td>23.76</td>
</tr>
</tbody>
</table>

Conversion factors

1 atm = 760 torr = 1.01325 x 10^5 pascals
General Chemistry Laboratory—Quiz

SHOW ALL OF YOUR WORK!!!

1. Balance the equation.

\[
\text{Al(NO}_3\text{)}_3(aq) + \text{NaOH(aq)} \rightarrow \text{Al(OH)}_3(s) + \text{NaNO}_3(aq)
\]

2. The Al(OH)_3 product in the above equation is a solid and settles to the bottom of the reaction vessel. What is the maximum mass (theoretical yield) of Al(OH)_3 that could precipitate from a reaction of .00900 moles of Al(NO_3)_3 and .0225 moles of NaOH?

Answer: _____________________________

3. If .450 grams of Al(OH)_3 product was actually produced, what is the percent yield?

Answer: _____________________________

4. From your lab notebook:

When conducting experiments on the relationship between pressure, volume, and temperature of a gas sample, the Erlenmeyer flask apparatus was used to:

(a) determine that the relationship between volume and pressure is inverse
(b) determine that the relationship between temperature and pressure is direct
(c) determine that the relationship between volume and temperature is direct
(d) determine that the relationship between pressure and temperature is inverse
General Chemistry Laboratory—Quiz

A student is preparing to do a titration. Answer the following questions about correct procedures.

True or false:

_____ (1) The pipet should be cleaned with a brush and soap solution before use.

_____ (2) The titration should be terminated when a drop of titrant causes color change that does not disappear after swirling.

_____ (3) The analyte should be contained in an Erlenmeyer flask.

_____ (4) Water added to the titrant will not affect titration results because the number of moles of solute in the titrant sample will not change.

_____ (5) The burets in our laboratory should be read to the tenths place.

_____ (6) The final step before filling a buret for a titration is to rinse it with deionized water.

(7) A titration is set up so that a standard solution of HCl is in a buret and 15.0 mL of NaOH solution of unknown concentration is in a flask. The HCl has a known molarity of 1.315 M. The initial buret reading is 0.46 mL and at the end point the buret reading is 24.88 mL.

(a) Write the equation for the reaction between NaOH and HCl.

(b) Using unit factors, calculate the number of moles of HCl used and then determine the number of moles of NaOH in the 15.0 mL sample.

(c) Determine the molarity of the NaOH solution.
From your lab notebook:

Write the reaction used by your group to produce a gas sample for the lab during which you determined the value of the gas law constant, R.

Write the reaction for the production of the bright yellow precipitate produced during the 5th week of general chemistry lab.

Give the formula needed for calculating standard deviation.
General Chemistry Laboratory—Quiz

A student is observing reactions of metals with cold water, hot water, cold acid, hot acid, and various metal salts.

Ca metal reacts with cold water. Write the reaction in formula unit form below:

Ni metal does not react with cold or hot water, but will react with hydrochloric acid. Write the reaction in formula unit form below:

Would you expect calcium nitrate to react to with nickel metal? ________

If so write the formula unit reaction below: (If not, write “no reaction.”)

Would you expect nickel(II) nitrate to react to with calcium metal? ________

If so write the formula unit reaction below: (If not write “no reaction.”)

The most important safety rule for diluting acids is:
From your lab notebook:

How many significant figures are in each number given below?

0.000524 _____  1.0020 _____  2.00 x 10^{-6} _____  2.00 x 10^{17} _____

When you produce a gas in a room temperature chemical reaction and collect the gas over water you must:

(a) correct the gas sample temperature for the influence of the water’s temperature
(b) correct the gas sample pressure by subtracting the water vapor pressure at room temperature
(c) correct the gas sample pressure by adding the water vapor pressure at room temperature
(d) correct the number of moles of gas produced by the reaction by subtracting out the number of moles of water vapor

If a solid product from a reaction is collected and dried, but the percent yield calculated is over 100%, the probable cause of this error is:
Use the appropriate equations to complete the calculations indicated. SHOW ALL OF YOUR WORK!

An alum has the formula NH₄Cr(SO₄)₂·12H₂O. Assign correct oxidation numbers to each element in the compound.

\[
\begin{align*}
\text{N: } & \quad \text{Cr: } \quad \text{S: } \quad \text{O in SO₄²⁻: } \quad \text{O in H₂O: }
\end{align*}
\]

Calculate the formula weight for NH₄Cr(SO₄)₂·12H₂O

**TODAY’s reaction** to produce an alum is:

\[
2\text{Al(s)} + 2\text{KOH(aq)} + 4\text{H₂SO₄(aq)} + 22\text{H₂O(l)} \rightarrow 2\text{KAi(SO₄)₂•12H₂O(s)} + 3\text{H₂(g)}
\]

If you started the reaction with 3.75 grams of aluminum metal, what is the theoretical yield of KAI(SO₄)₂•12H₂O(s) ?

If only 7.75 grams of alum were produced, calculate the percent yield for the reaction.

Describe the correct process for diluting an acid. Include all safety precautions!
**From your lab notebook (second chance!):**

Write the equation for the reaction between aqueous HCl and NaOH.

In a titration experiment, 25.00 mL of HCl was the analyte and 0.1452 M NaOH was used as the titrant. The initial buret reading was .25 mL and the final buret reading was 17.82 mL. Calculate the molarity of the HCl solution. SHOW ALL OF YOUR WORK!
General Chemistry Laboratory—Quiz

Identify the type of bond you would expect to occur between the following atoms by calculating the difference in electronegativities.

(a) K and Cl
(b) B and O
(c) Ba and F
(d) N and S

For each pair of bonded atoms sharing a single covalent bond, circle the one with the more polar bond. Also use an arrow (→) to show the direction of polarity in each bond. (The head of the arrow should point toward the atom with that would be partially negative in charge.)

(a) C—O and C—N
(b) Ga—As and In—P
(c) P—C and P—N
(d) N—H and C—H

Explain why soap works:
From your lab notebook (second chance):

Use the Rydberg equation to calculate the wavelength of light that would be absorbed by an electron moving from the first energy level to the fifth energy level in a hydrogen atom.

What is the frequency of the light in the problem above?
General Chemistry Laboratory 131

Final Exam Fall 2009

You may use your laboratory notebook as a resource for this test.

A calculator will be provided

Name: ______________________

Section: ________________

TA: ______________________
Five ecology students were out in the forest performing an experiment to determine the average circumference of California Redwoods. They chose four trees of varying sizes. Using a single metric tape measure each student measured each tree. The data retrieved is as follows.

<table>
<thead>
<tr>
<th>Tree</th>
<th>Student #1</th>
<th>Student #2</th>
<th>Student #3</th>
<th>Student #4</th>
<th>Student #5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree #1</td>
<td>5.22</td>
<td>5.15</td>
<td>5.27</td>
<td>5.70</td>
<td>5.32</td>
</tr>
<tr>
<td>Tree #2</td>
<td>7.92</td>
<td>7.92</td>
<td>7.84</td>
<td>8.15</td>
<td>7.96</td>
</tr>
<tr>
<td>Tree #3</td>
<td>11.54</td>
<td>11.74</td>
<td>11.56</td>
<td>11.60</td>
<td>11.68</td>
</tr>
<tr>
<td>Tree #4</td>
<td>15.12</td>
<td>15.34</td>
<td>15.26</td>
<td>15.56</td>
<td>15.24</td>
</tr>
</tbody>
</table>

Given this information, answer the following questions. (Note: Make sure you follow all significant figure rules when performing calculations.)

___ 1. What is the median circumference for Tree #3?
   (A) 11.624 m   (B) 11.62 m   (C) 11.60 m   (D) Cannot be determined.

___ 2. What is the mean circumference for Tree #4?
   (A) 15.3 m   (B) 15.30 m   (C) 15.26 m   (D) Cannot be determined.

___ 3. What is the standard deviation for the measured circumference of Tree #2?
   (A) .116 m   (B) .104 m   (C) .195 m   (D) Cannot be determined.

A student performed an experiment to determine the empirical formula of a compound containing chromium (Cr) and oxygen (O). The student heated 0.4550 g of pure Cr wire in an excess of air, cooled the sample, and weighed it. The mass of the compound formed was 0.8749 g. The molar masses of Cr and O are 52.00 g mol⁻¹ and 16.00 g mol⁻¹ respectively. Given this information, answer the following questions.

___ 4. The number of moles of Cr in the compound is
   (A) 1.683 x 10⁻²   (B) 8.075 x 10⁻³   (C) 2.624 x 10⁻²   (D) 8.750 x 10⁻³

___ 5. The empirical formula of the compound is
   (A) CrO   (B) CrO₂   (C) CrO₃   (D) CrO₄
In trying to determine the value of R, a student obtained the following data by decomposing \( \text{H}_2\text{O}_2 \) to form \( \text{O}_2 \) gas. The decomposition equation for \( \text{H}_2\text{O}_2 \) is:

\[
2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2
\]

The \( \text{O}_2 \) gas was collected over water in a gas buret. The temperature of the gas sample and pressure of the gas sample were recorded. The vapor pressure of water at the experimental temperature was determined to be 21.11 torr.

<table>
<thead>
<tr>
<th>initial buret reading:</th>
<th>0.20 mL</th>
</tr>
</thead>
<tbody>
<tr>
<td>buret reading:</td>
<td>20.97 mL</td>
</tr>
<tr>
<td>water temperature reading:</td>
<td>23.3 °C</td>
</tr>
<tr>
<td>moles of hydrogen peroxide:</td>
<td>.00155 moles</td>
</tr>
<tr>
<td>pressure of sample collected:</td>
<td>720 torr</td>
</tr>
</tbody>
</table>

6. Express the pressure of the \( \text{O}_2 \) gas collected in atmospheres (correct for \( \text{H}_2\text{O} \) vapor pressure):

   (A) .947 atm  (B) .920 atm  (C) .975 atm  (D) 1.056 atm

7. Calculate R (in L⋅atm/mol⋅K) based on the information given above.

   (A) 0.0888  (B) 0.0856  (C) 0.0832  (D) 0.0778

8. Another student experimentally determined the value of R to be 0.0798 L⋅atm/mol⋅K. The accepted value is 0.0821 L⋅atm/mol⋅K. Calculate the student’s percent error.

   (A) 2.88%  (B) 10.3%  (C) 2.80%  (D) 9.72%

Boyle’s Law relates pressure and volume of an ideal gas. This relationship can be easily observed by varying the volume occupied by a sample of gas in a syringe while measuring the change in pressure. Given the following information, answer questions 9 and 10.

<table>
<thead>
<tr>
<th>Volume (mL)</th>
<th>Pressure (atm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4</td>
<td>4.167</td>
</tr>
<tr>
<td>5.1</td>
<td>1.961</td>
</tr>
<tr>
<td>7.4</td>
<td>1.351</td>
</tr>
<tr>
<td>10.3</td>
<td>0.971</td>
</tr>
<tr>
<td>12.2</td>
<td>0.820</td>
</tr>
</tbody>
</table>

9. The relationship between volume and pressure is a(n) _________ relationship.

   (A) linear  (B) inverse  (C) direct  (D) both A & B

10. Using the provided data, you could predict that the same sample compressed to 1.0 mL would have a pressure reading of:

   (A) about 4 atm  (B) about 6 atm  (C) about 10 atm  (D) about 12 atm

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The relationship between temperature and pressure of an ideal gas are related and can be easily observed by varying the temperature of gas in a constant volume container and measuring the change in pressure. Given the following information, answer the following questions.

<table>
<thead>
<tr>
<th>Temp (K)</th>
<th>Pressure (atm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>275.0</td>
<td>0.935</td>
</tr>
<tr>
<td>296.2</td>
<td>1.007</td>
</tr>
<tr>
<td>333.5</td>
<td>1.134</td>
</tr>
<tr>
<td>373.9</td>
<td>1.271</td>
</tr>
</tbody>
</table>

___11. The relationship between temperature and pressure is best described by the equation

(A) PT = k  (B) PT = 1  (C) P/T = 1  (D) P/T = k

___12. NaCl is a soluble salt. This means that in aqueous solution it will:

(A) conduct electricity  (C) produce individual NaCl units
(B) turn in to Na metal and chlorine gas  (D) none of the above

___13. A substance that is a limiting reagent will:

(A) limit the amount of product that can be produced  (C) limit the speed of the reaction
(B) limit the amount of reactant that dissolves  (D) all of the above

___14. Given the following reaction with the number of moles used of each reactant, how many moles of the precipitate can be produced?

\[ \text{Pb(NO}_3\text{)}_2(aq) + 2\text{KI}(aq) \rightarrow \text{PbI}_2(s) + 2\text{KNO}_3(aq) \]

# of moles: \[ \begin{array}{cc}
3.00 & 1.50
\end{array} \]

(A) 1.50 moles  (B) 0.75 moles  (C) 3.00 moles  (D) not enough information given

___15. Record the temperature shown on the thermometer below to the correct number of significant figures.

![Thermometer Image]
Draw the electron dot structures for carbon monoxide and carbon dioxide and then answer questions 16 and 17.

___16. The bond between carbon and oxygen in carbon monoxide consists of:

(A) a strong σ bond  (B) two σ bonds and a π bond  (C) a σ bond and a π bond  (D) a σ bond and two π bonds

___17. The carbon in carbon dioxide has

(A) no lone pairs  (B) one lone pair  (C) two lone pairs  (D) four lone pairs

Given the following data answer questions 18-20.

<table>
<thead>
<tr>
<th>Metal Sample</th>
<th>Reaction with cold water</th>
<th>Reaction with hot water</th>
<th>Reaction with cold acid</th>
<th>Reaction with hot acid</th>
<th>Reaction with Cu²⁺ in salt</th>
<th>Reaction with Zn²⁺ in salt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pt</td>
<td>no rxn</td>
<td>no rxn</td>
<td>no rxn</td>
<td>no rxn</td>
<td>no rxn</td>
<td>no rxn</td>
</tr>
<tr>
<td>Pb</td>
<td>no rxn</td>
<td>no rxn</td>
<td>no rxn</td>
<td>slow rxn</td>
<td>rxn</td>
<td>no rxn</td>
</tr>
<tr>
<td>Mn</td>
<td>no rxn</td>
<td>slow rxn</td>
<td>rxn</td>
<td>fast rxn</td>
<td>rxn</td>
<td>rxn</td>
</tr>
<tr>
<td>Fe</td>
<td>no rxn</td>
<td>slow rxn</td>
<td>slow rxn</td>
<td>rxn</td>
<td>rxn</td>
<td>no rxn</td>
</tr>
<tr>
<td>Na</td>
<td>slow rxn</td>
<td>fast rxn</td>
<td>fast rxn</td>
<td>fast rxn</td>
<td>fast rxn</td>
<td>fast rxn</td>
</tr>
</tbody>
</table>

___18. Which metal is more active?

(A) Zn  (B) Pb

___19. Which metal is the most active metal?

(A) Pt  (B) Pb  (C) Mn  (D) Fe  (E) Na

___20. Choose the list that correctly shows the activity of the elements as predicted by the data above:

(A) Na > Mn > Fe > Pb > Cu > Zn > Pt  (B) Na > Mn > Zn > Fe > Pb > Cu > Pt
___21. A simple model of bonding assumes that atomic radii determine bond length. We made this assumption when using the Cambridge Crystallographic Data Base to determine atomic radii. Given the following atomic radii choose the bond lengths that are consistent with this assumption. (You may choose more than one correct answer.)

<table>
<thead>
<tr>
<th>Atom</th>
<th>Radius (Å)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>.320 Å</td>
</tr>
<tr>
<td>Cl</td>
<td>.990 Å</td>
</tr>
<tr>
<td>O</td>
<td>.730 Å</td>
</tr>
<tr>
<td>C</td>
<td>.770 Å</td>
</tr>
</tbody>
</table>

- (A) CH bond length in CH₄: 1.50 Å
- (B) HCl bond length in HCl: 1.11 Å
- (C) CCl bond length in CCl₄: 1.76 Å
- (D) HO bond length in H₂O: 1.05 Å

___22. A flame test was performed on various metal salts. A characteristic color is observed for strontium salt solutions. The color is observed because:

(A) The strontium is reacting with oxygen in the air.
(B) The strontium is really colored and when you “burn off” the water you can see the color.
(C) The electrons in the strontium atom are being removed.
(D) The electrons in the strontium ion are absorbing energy and then releasing energy in the form of colored light.

___23. If 17.57 mL of 1.23 M NaOH is used to reach the endpoint in the titration of a 25.00 mL sample of HCl, what is the molarity of the HCl solution?

- (A) 0.864 M
- (B) 1.73 M
- (C) 1.75 M
- (D) 0.875 M

___24. What is the general trend in the first ionization potential as you move from left to right across a period in the periodic chart?

(A) ionization potential increases
(B) ionization potential does not change
(C) ionization potential decreases
(D) no trend in ionization potential

___25. The molecular geometry of SF₆ is:

(A) see-saw
(B) tetrahedral
(C) square planar
(D) trigonal bipyramid

___26. The electronic geometry of BBr₃ is:

(A) tetrahedral
(B) T-shaped
(C) pyramidal
(D) trigonal planar

___27. Calculate the number of moles of KOH that would be needed to react with 2.50 grams of Al metal to produce alum, using the same reaction used in Chem 131 lab. (Put the number in the blank!)
28. When diluting a strong acid, you should follow strict safety procedures. These include all of the following except:

(A) Always add the acid to the water.
(B) Pour and use concentrated acids under a vent hood.
(C) Never rinse spills on your skin with water; this can cause intense burns.
(D) Never pour strong acids or bases above eye level.

29. Soap is:

(A) a salt         (B) an organic molecule         (C) a covalent molecule

30. A polar covalent bond occurs when:

(A) any two nonmetal atoms bond
(B) any two non-identical nonmetal atoms bond
(C) any two identical nonmetal atoms bond
(D) a metal atom and a nonmetal atom bond
Slide 1. This podcast addresses how to safely use acids in the laboratory.

Slide 2. Acids or bases purchased for laboratory use are usually in concentrated form. Concentrated acids and bases have extremely high molarities and must be handled with special precaution.
Concentrated acids should be handled under the hood.

**Slide 3.** Concentrated acids or bases should be handled under the hood. Often it will be necessary to prepare a solution of lesser molarity. To prepare a diluted acid solution use the $M_1V_1 = M_2V_2$ formula to determine the amount of concentrated acid required. Under the hood and wearing safety goggles and an apron (or lab coat) and gloves pour the desired amount of concentrated acid.

To dilute an acid there is one simple rule: Always Add Acid!

**Slide 4.** There is one simple dilution rule for acids: Always Add Acid! ALWAYS ADD ACID! The dissolution of a concentrated acid in water can produce a LOT of heat. If water is added to concentrated acid, the heat produced could cause splattering and you could burn yourself. Instead add some water to the vessel in which you will dilute the acid, a volumetric flask in this photo, and then add the ACID to the water. If more water is required to complete the dilution it may be added at this time.
Slide 5. Acid solutions that are not concentrated should still be handled with care. If their molarity is greater than 1 M, they will often be stored in containers with ground glass coin top stoppers. They’re called coin top stoppers because a glass disk on top of the stopper is shaped like a coin. To use type of stopper properly turn your hand palm up and lift the stopper by grasping the coin between two fingers. Now pour the desired amount of acid, still holding the stopper in your hand, as shown. Avoid placing the stopper on the bench top. This would allow any spilled acid to get on the stopper and may cause an acid burn for the next person who uses it.
An accident?  

A large spill may require using the safety shower.

Acid in eyes requires 20 minutes of flushing with water at the eye wash station.

Slide 6. We don’t expect any large spills, but we should always be prepared. Small spills on your skin should be flushed thoroughly with water. Acid accidentally splashed in your eyes is a serious problem. Notify your lab partner and go immediately to the eye wash station. Flush your eyes with eyes OPEN for 20 minutes. In the event that you spill a large amount of high molarity acid on your clothing, it is important to make sure that the clothing is not in contact with your skin. Notify your TA immediately…we will clear the lab…remove the clothing and use the safety shower to flush the affected area thoroughly. Wearing an apron and goggles should eliminate any need to use these safety devices. A laboratory is a safe place to work if you will follow appropriate safety rules you shouldn’t have any difficulty using acids safely.
**Slide 1.** We will be using digital balances to determine the mass of samples in our laboratory.

**Slide 2.** The balances are sensitive to air currents in the room and around the balance. For this reason do weigh hot or cold items on the balance. When they cool or warm air currents are produced. In addition you’ll notice that there is a small air current shield, a heavy plastic ring that sits around the balance pan. Please leave this in place. It can help prevent air currents from altering the mass reading.
Slide 3. To determine the mass of an item, check to make sure that the balance readout is showing zero grams. If it isn’t press the “zero” button and then after the empty balance is reading zero grams, place the item to be weighed in the center of the balance pan. Record all of the digits shown on the readout.

Slide 4. If you wish to determine the mass of a chemical, only, you might choose to tare the balance by pushing the “zero” button while the container to be used to contain the chemical is ON the balance pan. After taring, do not remove the container, but leave it on the balance pan.....
Slide 5. .....while you add the desired amount of chemical. It is important to realize that taring by pushing the zero button is only useful when you will not need to know the mass of the container at any point in the experiment. If you are not certain whether or not you will need to know the mass of the container, weigh the container first, add the chemical, record the weight of the container PLUS chemical and then you can take the difference to determine the mass of JUST the chemical. Please remember to clean up the balance area when you are finished. Chemicals spilled around the balance pan can impair the function of the balance and affect later users.
Slide 1. A crucible is a small ceramic container that can withstand very high temperatures. It has a loosely fitting lid. For this week’s lab you will use it to contain magnesium ribbon that will be heated with a Bunsen burner and allowed to react with oxygen in the atmosphere.

1. Position the crucible in the clay triangle on a ring stand.
2. The crucible lid should be slightly ajar.
3. Adjust the Bunsen burner flame.

Slide 2. In the photo notice that the crucible is placed in a clay triangle on a ringstand ring and the lid is slightly ajar. When you light a Bunsen burner and adjust the flame properly, it should have an inner cone and an outer cone. The tip of the inner cone is the hottest part of the flame and the tip of the inner cone should be touching the bottom of the crucible if it’s positioned correctly.
**Slide 3.** You will want to use crucible tongs to lift the lid of the crucible and to lift the crucible on and off of the clay triangle. This may seem a bit obvious, but a hot crucible looks exactly the same as a cold crucible, so be very careful and always use tongs.

**Slide 4.** There is a wooden board hanging at on the lab bench in front of your lab bench section. This board is provided for you to put warm items on. When the crucible has cooled in the clay triangle for the prescribed five minutes, you can move it to the wood board to cool further. If you put it on the wood board too soon it will actually burn a little circular pattern on the wood board. You don’t want this to happen, so make sure that you’ve cooled it before you place it on the board.
Use an evaporating dish to carry the crucible to the balance room.

**Slide 5.** When your crucible is COMPLETELY cooled you can take it to the balance room to weigh it and you should carry it in a small evaporating dish so that if the lid slips off of the crucible while you’re transporting it you’ll be unlikely to drop it and break it.
Planning an Experiment

INCLUDE THESE STEPS IN YOUR TEAM LAB REPORT!

**Slide 1.** Planning an Experiment. You need to include these steps in your team lab report because when planning an experiment there are definite steps you must take.
Research Questions

INCLUDE IN “TEAM BEGINNING QUESTIONS!”

- Determine what you already know about whatever you will be researching.
- Determine how you can test how a substance acts or how a process works and what variables you might be able to adjust.
- Write a research question that includes a variable that you will adjust for the substance or process and asks what the effect of the variation will be.

**Slide 2.** These steps should be included with your team beginning questions. First, you’ll need to determine what you already know about whatever you’ll be researching. Make a brief list. For example last week you knew that alum was a flocculent and that alum was a solid that could be dissolved in water. Just a short list.

Then determine how you could test what you think you already know and then what you might be able to vary in the process that might have an effect on the properties or process that you’re going to test. Again using last week’s lab as an example, you could decide to test the alum to see if it was acting as a flocculent by adding it to muddy water. You could have decided to vary the type of muddy water, or the temperature of the muddy water, or the amount of alum added to the muddy water, to name a few possibilities.

Finally, you need to write a research question that includes the variable that you will adjust and asks what effect the variation will have. From the alum lab again, a research question might be: Does alum cause flocculation of muddy water? And then a secondary question: Does the temperature of water affect the extent of flocculation?
Experimental Design

INCLUDE IN “TEAM PROCEDURE SUMMARY!”

- Determine how you will vary your “variable” and how you will keep all other potential variables constant.

- Plan an control sample or samples. A control is exactly like the test sample in every way except for the “variable”. **Think carefully about your control samples!**

**Slide 3.** The steps in this slide need to be included in the team procedure summary. In the procedure summary you will need to record how you will vary the “variable” and how you will keep other variables constant. You’ll also need to plan control samples.

For the alum experiment you could have planned to make 6 beakers of muddy water. Each beaker could have contained one tsp of clay #2, and one scoopula tip of soap powder in 200 mL of water, so that all 6 beakers were identical. The first 3 could be your control beakers and the 2nd three could be your experimental beakers. You could have used one control and one experiment at 0 °C, one control and one experimental at room temp, and one control and one experimental at a higher temperature. To the experimental beakers you would add a determined amount of alum. So you see that the 3 control and the 3 experimental beakers at would have identical contents except for the addition of alum to the experimental beakers. You need to think about planning controls very carefully. They must be exactly like the experimental comparison in every way EXCEPT for the ONE variable you are testing.
Slide 4. The next two categories of information need to be included in “team observations and data” and “team calculations and graphs.” You need to collect quantitative and qualitative data as is appropriate and be sure to record the data in your lab notebook...don’t try to just depend on your memory. In your calculations and graphs you may choose to include drawings or photographs that show how the samples LOOK as qualitative data. This is a very effective way to illustrate for readers what you have observed. If you have quantitative data, graphs may be helpful, but you will definitely want include any calculations. Remember that only one example of each type of calculation has to be included.

Slide 5. And finally you need to make sure that you answer your beginning research questions and then clearly describe the interpretation of the data to support the claims in team evidence and analysis. In this section you also need to include any difficulties encountered that may have resulted in qualitative or quantitative consequences.
Slide 1. Filtering solids suspended in solution.

Filtration is a method of separating a solid from a liquid. You’ll learn two common filtration methods in this presentation.

Slide 2. Filtering is a method of separating a solid from a liquid. In the lab you may need to separate the solid product of a reaction from a solution. In this case you’d be especially interested in keeping the solid. Sometimes the filtrate or liquid portion of the solid/liquid mixture is important in a process. For this reason, you should always use clean glassware and follow filtration procedures carefully. We’ll discuss two filtration methods in this presentation.
Gravity Filtration

Supplies needed:
- funnel
- filter paper
- wash bottle
- Erlenmeyer flask

**Slide 3.** The first is gravity filtration. As is implied by the name, the force of gravity is used to separate the solid and liquid. Using this method the mixture is poured into a funnel lined with filter paper. The solid collects in the filter paper and the liquid passes through the filter paper and is collected in an Erlenmeyer flask.

1. Fold the filter paper twice and open in a cone shape. Place in funnel.

2. Wet the filter paper so that the paper fits tightly against the sides of the funnel.

3. Using a stirring rod, pour the solid containing solution into the funnel—NEVER over fill!

**Slide 4.** After gathering the needed supplies, prepare the filter paper by folding it in half twice and then opening it into a cone shape. Place the filter paper cone into the funnel and wet it using a wash bottle filled with deionized water so that the paper fits tightly against the sides of the funnel. Finally pour the liquid/solid mixture into the filter-paper lined funnel. Keep the level of the liquid in the funnel below the edge of the filter paper. You may wish to pour down a glass stirring rod as shown in the photo. This will keep the stream of liquid from running down the side of your beaker. When all of the mix has been transferred to the funnel, allow the liquid to completely drain.
Slide 5. The second filtering method that is common is vacuum filtration. The principle is the same, but a vacuum is used to pull the liquid through more quickly, therefore the apparatus needed is slightly different. Notice the funnel in the photo. It’s called a Buchner funnel and is wider than the funnel used for gravity filtration. It is placed in a rubber collar before being placed into the neck of a SIDE ARM Erlenmeyer flask.

1. Place a filter paper flat in the bottom of the Buchner funnel.

2. Wet the filter paper so that it remains flat against the bottom of the funnel.

Slide 6. To prepare this apparatus for use, place a filter paper flat in the bottom of the Buchner funnel and once again wet the paper with deionized water so that it will remain flat. You will notice that the Buchner funnel has a series of small holes in its base. These should all be covered completely by the filter paper.
Slide 7. Next you will need to locate one of the water aspirators in the trough sinks between the lab benches. Connect rubber tubing to the aspirator as shown. Connect the other end of the rubber tubing to the side arm of the Erlenmeyer flask as shown.

Slide 8. It is VERY important to clamp the set up to a ringstand to prevent the flask from tipping! Finally you can filter the mix by turning on the water at the aspirator faucet and then pouring the mixture into the funnel while holding the funnel firmly against the collar.
Slide 9. When all of the liquid/solid mixture has been separated, ALWAYS remove the rubber tubing from the side arm BEFORE turning off the water aspirator. If you don’t, water from the faucet may back up into the Erlenmeyer flask and if you are saving the filtrate for your next step in a process this could be a tragedy!

Slide 10. So when should you use gravity filtration and when should you used vacuum filtration? Generally in this course you will use gravity filtration, but larger amounts of product may require vacuum filtration. In class, we will suggest the labs that require vacuum filtration.
Collecting a gas sample

**Slide 1.** This podcast addresses how to collect a gas sample in the lab.

**Slide 2.** The picture shows a gas collection apparatus. On the left you see a leveling bulb, in the middle a gas buret, and on the far right a reaction vessel. You will have a leveling bulb that is already connected to a gas buret provided for your use. You will need to assemble the apparatus as shown and then fill the leveling bulb with water. As water is added to the leveling bulb, the water will rise in the gas buret until the water level in the gas buret and leveling bulb are equivalent. In your set up you may choose to use a large test tube as a reaction vessel rather than an Erlenmeyer flask.
Slide 3. The reason we’re using this set up is because it will allow us to trap the gas AND determine the pressure of the gas sample that we collect. When the water levels in the leveling bulb and gas buret are even, we can assume that the pressure of the gas inside the gas buret is equivalent to atmospheric pressure. So you will do a reaction in the reaction vessel, collect the gas sample in the gas buret and make sure that you lower the leveling bulb as the gas is collected so that the level of the water in the leveling bulb matches the level in the gas buret after you sample collection.

Slide 4. Think through your experiment carefully before beginning, because it’s essential that you collect the sample correctly!
**Slide 1.** When reading the level of the liquid in glassware always read the level at the bottom of the curved liquid surface, which is called the meniscus.

**Slide 2.** You should not hold the glassware while taking a reading; it may be tilted and give an inaccurate reading.
Slide 3. In order to get an accurate reading you should set it on the counter…

Slide 4.….and then move so that you are looking at the meniscus at eye level. This is the most accurate way to read the level of a meniscus in glassware.
Slide 1. The reactivity of metals can be compared by experimentally determining which metals react most vigorously in set conditions.

Definition of “reactivity”

A standard way to define reactivity for metals is to determine which ones react more intensely with:

- Room Temperature H₂O
- Steam (water vapor at 100° C)
- Room temperature acid
- Warm acid

Slide 2. The standard way to compare reactivity is to determine which metals react with water, either room temperature water or steam, which is just water vapor at 100 °C and which metals react with acid. The acid can be either room temperature acid or warmed acid.
Definition of Reactivity

The metals can then be placed in an order called an “activity series”:

M that reacts with $\text{H}_2\text{O}$ >  
M that reacts with steam >  
M that reacts with acid >  
M that reacts with warm acid

Slide 3. A metal (M) that reacts with room temperature water will also react with steam and acid at any temperature. A metal that does not react with room temperature water, but reacts with steam will also react with acid at any temperature. A metal that does not react with water or steam but reacts with room temperature acid will react with warmed acid. And finally a metal that does not react with water, steam or room temperature acid may or may not react with warmed acid. On the basis of these reactions, the metals can be placed in an activity series. Those that react with water are most active, those that react with steam (but not cold water) are next most active, those that react with acid (but neither water nor steam) are next in the series, and finally those that only react with warmed acid are least active.
Reactions with water or acid

In these reactions the metal atoms replace hydrogen in water or acid.

\[ M (s) + H_2O (l \text{ or } g) \rightarrow M(OH)_n(aq) + H_2 (g) \]

\[ M (s) + HCl (aq) \rightarrow MCl_n (aq) + H_2 (g) \]

**Slide 4.** In each of these reactions the metals atoms replace hydrogen in the water or acid. This means that they are MORE ACTIVE than hydrogen... bumping it out of its position in a compound. The reactions are shown on this slide. Notice that the number of hydroxide groups and the number of chlorides are given by “n”. This number will vary depending on the oxidation state of the metal.

Reactions of metals with metal salts

- Another way to compare the reactivity of a metal is to test whether it reacts with a metal salt. (Especially important for metals that are not very reactive and do not react with either water or acid.)

\[ M (s) + MX_n(aq) \rightarrow MX_n(aq) + M (s) \]

A metal that reacts with a metal salt is MORE active than the metal in the salt!

**Slide 5.** Another way to compare the reactivity of a metal is to test whether it reacts with a metal salt. (This is especially important for metals that are not very reactive and do not react with either water or acid.) In this type of reactivity test a drop of metal salt is placed on a metal sample. Evidence of reaction indicates that the solid metal is MORE ACTIVE than the metal in the metal salt. If NO evidence of reaction is seen, the metal in the metal salt is more active. Notice from the reaction that is shown, that once again the more active metal, the metal solid, is “bumping” the less active metal out of the compound. Again the values for “n” will be determined by the oxidation state of the metals in the compounds.
Slide 6. A few points to remember: The metal activity series must be determined experimentally. For your lab report, write a correct equation for every reaction you observe. When writing the correct reaction equations, select the correct values for “n” by determining the oxidation state. If there is more than one oxidation state for a metal that you are testing, use the oxidation state that is shown in bold on your periodic chart; this is the most common oxidation state. Your “claims” should include the activity series you have determined!
Slide 1. Using pipets…the correct way!

Slide 2. There are three common types of pipets used in our laboratory. Some have graduated milliliter markings and some don’t. In this podcast you will learn how to use each type properly.
The first type of pipet is a Mohr pipet. It is graduated and has a baseline mark.

**Slide 3.** The first type is called a Mohr pipet and it has graduated markings and also has a baseline mark, which means the mark for the maximum amount that can be delivered is above the tip of the pipet. The pipet shown is a 10 mL pipet as the baseline indicates.

**Slide 4.** To use this type of pipet, draw the liquid into the Mohr pipet to the zero mark very carefully so that the meniscus is exactly at the zero mark.
Slide 5. Then release the desired amount of liquid. The volume released can be read from the graduated markings. With the pipet shown you could release any volume between 0 and 10 mL, but NEVER release liquid beyond the baseline. This pipet has been used to deliver 9.94 mL.

Slide 6. A second type of pipet is called a serological or “to deliver” pipet. It has graduated markings but no baseline mark. The pipet shown is a 10 mL pipet, but the final numerical marking is 9 mL. The graduations continue down the tip of the pipet.
**Slide 7.** For this pipet you should also draw the liquid to the 0 mL mark. Again, you can deliver between 0 and 10 mL, but if you are needing to deliver 10 mL you will need to release the liquid all the way to the tip of the pipet as shown on the next slide.

**Slide 8.** Some liquid may remain in the pipet tip. It is calibrated to take this into account, so do not use your pipet bulb to force out the remaining liquid.
A third type of pipet is the volumetric pipet that has no graduated markings and is used to deliver one amount.

Fill to the top mark.

Slide 9. The final type of pipet used in our laboratory is the volumetric pipet. It has no graduated markings and a single fill line. Volumetric pipets are used to deliver one amount. The pipet shown is a 10 mL volumetric pipet. In the photograph it is difficult to see the fill line because the fill line is etched in the glass, but it will always be visible just above the bulb of the volumetric pipet. You should fill the pipet to the fill line. A volumetric pipet has no baseline marking so you should release all of the liquid in the pipet.

Release to the tip.

Some liquid will remain in the tip. Touch the tip to the side of the container to release a hanging drop, but do not force out remaining liquid.

Slide 10. Again some liquid will remain in the tip. If a liquid droplet is hanging from the tip, touch the tip to the side of the delivery container. Again do not force out the remaining liquid. The pipet is calibrated to take into account the small amount that remains.
Slide 11. So, there are three types of pipets. Be sure that you know which type you are using BEFORE you begin your experiment.
Slide 1. Determining Significant Figures

Rules for determining the number of significant figures in a number

1. All digits that are not zeros are significant.
2. Captive zeros are always significant.
3. Leading zeros are never significant.
4. Trailing zeros following a decimal are significant, trailing zeros before a decimal are not significant.

Slide 2. There are some simple rules for determining the number of significant digits in a number. All digits that are not zeros are significant, but there are three different kinds of zeros that we need to consider.
Captive Zeros: ARE significant
( zeros "captured" between other digits)

Examples:

1004  2 captive “0”s,  
    but 4 significant figures!

5091.08  2 captive “0”s,  
    but 6 significant figures!

Slide 3. The first type of zero is a captive zero. Captive zeros are ALWAYS significant. These are zeros that are captured between other digits. There are two examples on the slide. In the first example, 1004, the two digits in the middle are zeros. They’re captive and so this number has four significant figures. In the second example, 5091.08, there are also two captive zeros which both count as significant digits, so this number has six significant digits.

Leading Zeros: ARE NOT significant
( Zeros leading the number)

Examples:

0.0086  3 leading “0”s  
    but only 2 significant figures

0.02088  2 leading “0”s, 1 captive “0”  
    so only 4 significant figures

Slide 4. Leading zeros are NOT significant; they are NEVER significant! Leading zeros lead the number and are just present to hold place value. So in the two examples given you can see that we do not count the leading zeros as significant digits.
Trailing Zeros: sometimes significant!
( Zeros at the end of a number)

Significant only after the decimal point

Slide 5. Trailing zeros are SOMETIMES significant. These are zeros at the END of a number. The simple rule is that they are significant ONLY if they appear after a decimal point. So in the first example, 0.0120, there are two leading zeros that are not significant and one trailing zero that is, so there are just three significant digits. For the second number you look only at the leading number that precedes the ten to the fifth power. There are three numbers after the decimal, two of which are trailing zeros. So the total number of significant digits in this number is four. In the final example 2500 there are two trailing zeros. Neither one appears AFTER the decimal point so neither are considered significant. This number only has two significant figures.
**Slide 1.** Simple Statistics: Measures of Central Tendency. We commonly calculate the mean, which is just the sum of measurements divided by the number of measurements and the median, which is simply the middle value. You should be familiar with calculating both of these. When the mean is approximately equal to the median, precision is considered to be high.

**Slide 2.** Sometimes we’re also interested in measures of variation such as deviation or standard deviation. For the example given here, there are five data points and the mean of these data points is 3.3. We can calculate the deviation for each of the data points by taking the difference between the measured value and the mean and then taking its absolute value. So 3.3 minus 2.4 equals 0.9, 3.3 minus 2.6 is 0.7, etc. There are five data points so there are five deviation values…one for each data point. Standard deviation is calculated by squaring each of the deviation values and adding them together then dividing that value by the number of data points minus one. This number is raised to the one half power which is the same as taking its square root. Standard deviation is the usual way that deviation is expressed in scientific reporting.
Slide 3. Percent error is the expression of the difference between a measured value and an actual value. If the measured value is 5.25 grams but you know that the actual value is 5.45 grams you can calculate the percent error by taking the difference, dividing by the actual value and multiplying by 100. You can only calculate percent error when an actual value is known.

Slide 4. Finally we might calculate percent yield. Percent yield is calculated when you do a reaction and you can use a balanced chemical equation to calculate the amount of a product that could be produced if all of the reactant was converted to product. In the real world this never happens! You might spill some or there might be other factors that limit the amount produced. But when you can calculate how much “could” be made it’s called the theoretical yield. If 34.75 grams could have been produced, but in the lab experiment you only isolated 23.82 grams, then you would calculate that you had a 68.55% yield, as shown. This number will never be greater than 100% because you can never make more than is theoretically possible.
Slide 1. This podcast will address the correct use of titration equipment.

Slide 2. To perform a titration you will need: a buret, a funnel, a small beaker, an Erlenmeyer flask, a volumetric pipet, a pipet bulb, and ringstand and a buret clamp. The buret should be positioned in the buret clamp as shown in the photo.
Slide 3. Three solutions are used in a titration. The titrant is a solution of very accurately known concentration that is dispensed using the buret. This means that you will fill the buret with the titrant. The analyte is the solution that you will be analyzing. Its concentration is NOT known. A sample of the analyte will be delivered to an Erlenmeyer flask. An indicator is used to indicate the completion of the titration.

Preparation of the buret

1. Use a buret brush to clean the buret
2. Pour a small amount of the titrant into the buret.
3. Rinse the buret thoroughly by tilting back and forth, then completely drain the buret.

Slide 4. To prepare the buret for titration, clean the buret using a buret brush and a small amount of soap solution. Rinse it thoroughly with water. It cannot be easily dried so instead use a funnel to pour a small amount of the titrant into the buret. Never fill a buret with an acid or base above eye level! If your titrant is a strong acid or strong base move the buret so that you are not pouring above face level. When you’ve poured a small amount of titrant into the buret with the stopcock closed, gently rinse the buret by tilting and turning the buret so that any water droplets are washed away by the titrant. After rinsing well with the titrant, completely drain the buret into a waste beaker.
Slide 5. The cleaned and titrant-rinsed buret can now be filled with titrant to be used in the titration. Fill the buret until the titrant level is between 0 and 1 milliliter. If there are bubbles in the tip of the buret, partially open the stopcock and gently tap the tip until no bubbles remain.

Slide 6. A buret is used in a titration to accurately measure the amount of titrant added to the analyte solution. After the buret has been prepared as described in previous slides, record the initial volume. The volume shown in the buret on the left is 0.44 mL. Watch significant figures as you read the volume. After completing the titration you will read the titrant volume again. Here the final volume shown in the buret on the right is 23.72 mL. Therefore the total volume added would be 23.72 mL minus 0.44 mL for a volume added of 23.28 mL.
Preparing the sample of unknown concentration

1. Obtain 100 mL of the analyte solution
2. Rinse a volumetric pipet with a small amount of the sample

Slide 7. We’ve discussed preparing the buret, now we’ll discuss preparing the analyte sample. If the analyte is a solid, an appropriate amount could be weighed and placed in an Erlenmeyer flask and dissolved in water. However often the analyte will already be in solution. In this case obtain a 100 mL sample in a small beaker. You will need to rinse the volumetric pipet, so draw a small amount of the analyte into the volumetric pipet and rinse in the same way that you rinse the buret. After draining the analyte used to rinse the pipet into a waste beaker, you may refill it with analyte solution to the fill mark.

3. Use the pipet to deliver an accurately measured sample to an Erlenmeyer flask
4. Add two drops of indicator
5. Use deionized water to rinse any sample that may have splashed on the sides down into the aliquot.

Slide 8. You’ll then use the pipet to deliver an accurately measured sample of the analyte to an Erlenmeyer flask, and then add two drops of indicator. Use deionized water to rinse any analyte that may have splashed on the sides down into the aliquot. The term aliquot simply means “portion” and that would be the portion of the analyte that you have delivered to the Erlenmeyer.
Slide 9. You’re now ready to begin titrating. Slowly open the buret stopcock to add titrant in a dropwise fashion to your sample in the Erlenmeyer. Gently swirl the analyte solution in the flask. There are different indicators used for titrations, so you will want to watch carefully for the appearance of the desired indicator color.

Slide 10. Often phenolphthalein is used as an indicator for acid-base titrations. For this indicator the solution should change from colorless to a light pink at the endpoint. As you approach the endpoint, each drop of titrant added will produce a small cloud of pink color, but it will disappear with swirling. You should stop the titration when a drop causes color change that does not disappear with swirling. This will be the endpoint. We’ve now discussed the procedure for titrating an unknown sample. Follow the procedure carefully. It will make a difference in the accuracy of your results.
Slide 1. The directions for using the Vernier data collection system are detailed. Be sure to follow them carefully. There are two common student errors that hinder data collection. The first is the misuse of the three-way valve when trying to trap a gas sample. The second is the incorrect identification of the type of temperature probe being used.

Slide 2. For each of these experiments you will need to trap a gas sample. The number of moles of gas that you collecting data on must be kept constant, so to set up the apparatus before data collection open the valve to the atmosphere. The blue “off” handle should point away from the opening to the atmosphere when you are collecting your sample.
“Trapping” the gas sample

Before beginning data collection CLOSE the valve to the atmosphere: the blue OFF handle should point toward the opening to the atmosphere.

Slide 3. Then to TRAP the gas sample before beginning data collection close the valve to the atmosphere. The blue “off” handle should point toward the opening to the atmosphere. This allows the gas pressure sensor to be open to the gas sample that is trapped in either an Erlenmeyer or syringe.
Slide 4. The second common student error is to select the incorrect type of temperature probe when you open the Vernier software. There are two types of temperature probes: the “direct connect” shown on the left and the “standard” shown on the right. The primary difference is that the standard temperature probe has a data box between the probe and the connection. You must select the correct type of probe as you open the experiment file or your data will be incorrect! If you see temperature readings that are not close to 25 °C at room temperature, then you’ll know you’ve made a mistake.

When doing your experiment you should notice a change in pressure when volume or temperature is changed. If you do not, re-check the valve alignment and the temperature probe selection.
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