Title

Making Visible the Complexities of Problem Solving: An Ethnographic Study of a General Chemistry Course in a Studio Learning Environment

Permalink

https://escholarship.org/uc/item/4549d919

Author

Kalainoff, Melinda Zapata

Publication Date

2013

UNIVERSITY OF CALIFORNIA

Santa Barbara

Making Visible the Complexities of Problem Solving: An Ethnographic Study of a General Chemistry Course in a Studio Learning Environment

A dissertation submitted in partial satisfaction of the
requirements for the degree Doctor of Philosophy
in Education

by

Melinda Zapata Kalainoff

Committee in charge:
Professor Danielle B. Harlow, Chair
Professor Julie A. Bianchini
Professor Judith L. Green
Dr. Grace A. Neff

September 2013

The dissertation of Melinda Zapata Kalainoff is approved.

Julie A. Bianchini

Judith L. Green

Grace A. Neff

Danielle B. Harlow, Committee Chair

May 2013

Making Visible the Complexities of Problem Solving:

An Ethnographic Study of a General Chemistry Course in a Studio Learning Environment

by

Melinda Zapata Kalainoff

ACKNOWLEDGEMENTS

I thank my mentor and friend, Dr. Judith Green, for her guidance, wisdom, and patience along this journey with me.

DEDICATION

For Sarah and Jacob

VITA OF MELINDA ZAPATA KALAINOFF

September 2013

EDUCATION

Bachelor of Science in Chemical Engineering, University of Notre Dame, May 1994
Master of Science in Engineering Management, University of Missouri, Rolla, May 1999
Master of Science in Chemistry, University of New Hampshire, September 2004
Master of Arts in Education, University of California, Santa Barbara, September 2012
Doctor of Philosophy in Education, University of California, Santa Barbara, September 2013 (expected)

PROFESSIONAL EMPLOYMENT

1994-Current	U.S. Army Officer, Corps of Engineers
2004-2007	Instructor and Assistant Professor, Department of Chemistry and Life Science, United States Military Academy, West Point, NY

PUBLICATIONS

Kalainoff, M., Lachance, R., Reigner, D., & Biaglow, A. (2012). A computer algebra approach to solving chemical equilibria in general chemistry. *Problems, Resources, and Issues in Mathematics Undergraduate Studies*, *22*(4), 284-302.

Kalainoff, M. Z. (2007). *Systematic Method Handbook CH152/102 (AY07)*. Department of Chemistry & Life Science, United States Military Academy, West Point, New York.

Kalainoff, M. (2004). Statistical thermodynamic properties of pure and mixed atomic clusters. Thesis submitted in partial fulfillment of the requirements for the Master of Arts degree in Chemistry, University of New Hampshire, p.196.

AWARDS

Honorary PhD, University of the Southwest, 2010.
HENAAC (Great Minds in STEM) Luminary Award, 2007.

ABSTRACT

Making Visible the Complexities of Problem Solving:

An Ethnographic Study of a General Chemistry Course in a Studio Learning Environment

by

Melinda Zapata Kalainoff

Studio classrooms, designed such that laboratory and lecture functions can occur in the same physical space, have been recognized as a promising contributing factor in promoting collaborative learning in the sciences (NRC, 2011). Moreover, in designing for instruction, a critical goal, especially in the sciences and engineering, is to foster an environment where students have opportunities for learning problem solving practices (NRC, 2012a). However, few studies show how this type of innovative learning environment shapes opportunities for learning in the sciences, which is critical to informing future curricular and instructional designs for these environments. Even fewer studies show how studio environments shape opportunities to develop problem solving practices specifically. In order to make visible how the learning environment promotes problem solving practices, this study explores problem solving phenomena in the daily life of an undergraduate General Chemistry studio class using an ethnographic perspective. By exploring problem solving as a sociocultural process, this study shows how the instructor and students co-construct opportunities for learning in whole class and small group interactional spaces afforded in this studio environment and how the differential demands on students in doing problems requires re-conceptualizing what it means to "apply a concept".

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter I: Introduction

Since reports of the state of science, technology, engineering and mathematics (STEM) undergraduate education in the 1990's (NRC, 1996, 1999; NSF, 1996), numerous innovative teaching, learning and assessment initiatives have emerged. One of these innovations in the area of learning environments, studio classrooms, has been recognized as a promising contributing factor in promoting collaborative learning in the sciences (NRC, 2011). Studio classrooms for the sciences are designed such that laboratory and lecture functions can occur in the same physical space. Thus far, the scant literature on research in undergraduate science studio classrooms has focused on quantitative studies based in student assessments (e.g., Cummings, Marx, Thornton, & Kuhl, 1999) and qualitative studies based in instructor perceptions of student achievement (e.g., Bailey, Kingsbury, Kulinowski, Paradis, & Schoonover, 2000). There are fewer qualitative studies that show what is happening in studio classrooms. As a result, there is little evidence of how the studio classrooms shape opportunities for learning in the sciences which is critical to informing future curricular and instructional designs for these environments.

The studio classroom is an alternative format to the traditional lecture hall and laboratory-based format typical of many undergraduate chemistry courses. Traditional undergraduate general chemistry courses are most often taught as two separate courses, a lecture course and a laboratory course. The lecture-based classroom (see Figure 1(A&B)) is usually made up of individual desks that face a central area where the instructor is located. Artifacts within this type of room might include blackboards and projection screens that serve as signals to orient students toward the "front" of the classroom. Because of socialization in these typically experienced school settings, student expectations in this type of undergraduate classroom, especially where there are large numbers of students, are that the

A. Lecture Hall, Hartwick College, New York, Circa 1960. (Photo used with permission of the Paul F. Cooper, Jr. Archives, Hartwick College. The original photo is located in the Paul F. Cooper, Jr. Archives, Hartwick College, Oneonta, NY.)

B. Lecture Hall, UC Santa Barbara, California, 2013.

Figure 1(A&B). Photos of a "typical" traditional lecture hall.

instructor will present the disciplinary content on the chalkboard or display slides on a large screen for the duration of class time. As such, the traditional general chemistry lecture course consists of an instructor at the front of the room writing class notes on the blackboards or showing slides on a projection screen while explaining theories, concepts, and processes to students.

The laboratory, on the other hand, serves a completely different purpose—to provide opportunities for students to engage in scientific practices such as planning and conducting investigations. The traditional chemistry laboratory course in the academic context is removed from the lecture hall in space and time (Bailey et al., 2000). This setting (see Figure 2(A&B)) is typically made up of long elevated tables called "benches" with drawers and cabinets underneath that house various glassware, measuring devices, and equipment to construct the experimental apparatus. A functioning laboratory must meet safety requirements such as eyewash stations, overhead shower station, and means for disposal of chemical waste.

In laboratory-based courses, students use concepts learned in the lecture to recreate chemistry experiments so that students have the opportunity to use procedures and tools used by chemists. At the entry-level courses, such as general chemistry, students usually conduct labs in two person groups as lab partners. Because all students on one side of a bench face in the same direction, other lab-partnered groups are 180 degrees away as shown in Figure 2. Bench sides are usually separated by an elevated area that houses piping for air and water or other equipment which can limits access between lab groups on either side of a laboratory bench. Additionally, both lecture and laboratory classroom environments are well entrenched within academic and disciplinary, as well as historical and cultural, traditions as evidenced by their persistence over time as shown in Figures 1(A&B) and 2(A&B).

A. Chemistry Laboratory, Oregon State University, Oregon, Circa 1915. (Photo is used with permission of the Special Collections & Archives Research Center, Oregon State University. The original photo is located in the Linus Pauling, Centenary Exhibit archive of the Special Collections & Archives Research Center, Oregon State University.)

B. Chemistry Laboratory, United States Military Academy, New York, 2013.

Figure 2(A&B). Photos of a "typical" traditional chemistry laboratory.

In traditional chemistry lecture and lab courses, students and instructors experience discontinuities because lecture and laboratory are not linked in time and place (Bailey et al., 2000). Since traditional lecture and laboratory are separate courses, a student’s instructor for lab may not be the same as the instructor for lecture (Bailey et al., 2000; Johnson & Morris, 1997). This discontinuity is also an artifact of university scheduling where, at some institutions, students may take the lab and lecture courses in different semesters or quarters.

These consequences of separate courses have led to efforts to bridge the disconnection in different ways. In one example, computer modeling and simulation were made available to students as an online exercise to transition students from lecture to the laboratory (Johnson & Morris, 1997). More common methods for reducing the disconnect is to align content (Johnson & Morris, 1997) or personnel (same instructor for lab and lecture) (Bailey et al., 2000). In an article about the history of the specific classroom in this study, Bailey et al. (2000) explains that even with attempts to link lecture and laboratory sections with the same instructors, students "still experienced a discontinuity of time, place, and instruction in the traditional lecture-lab format" (p. 195).

This issue prompted the institution in this study to seek a design solution outside of the traditional lecture and separate laboratory model (Bailey et al., 2000) towards what has been called a “studio” (Bailey et al., 2000; Breichner, Saul, Allain, Deardorff, & Abbott, 2000; Gottfried, Sweeder, Bartolin, Hessler, Reynolds, Stewart, Coppola, & Banaszak Holl, 2007). Although science-based studios vary by discipline, function, and resources available, the main characteristic of these studio settings is that lecture and laboratory time and functions are integrated into one learning environment.

The studio classroom also looks different than a traditional classroom. Where most lecture halls have desks facing the instructor, the typical studio classroom does not have an obvious front of the room. Instead, students occupy spaces in circular or rectangular formations at tables to facilitate collaborative activity in groups. In studio classrooms, groups may also have access to online resources through classroom computers at multiple workstations within their group table. In a chemistry studio, the tables also function as a "wet" laboratory environment where students can actually mix chemicals in conducting experiments (Apple & Cutler, 1999; Bailey et al., 2000). In this way, the lecture and laboratory functions can occur in the same time and place with the intent of facilitating student learning in a collaborative environment.

Figure 3. Photo of chemistry studio under study (Photo dated: 2010).

According to Bruffee (1999), "[C]ollaborative learning demonstrably helps students learn better - more thoroughly, more deeply, more efficiently- than learning alone” (p. xii). This may be understood within theories of learning that view science knowledge as socially constructed (Vygotsky, 1978; Bruner, 1985; Gergen, 2009; Kelly & Chen, 1999). Drawing on Vygotskian learning theory, Bruner (1985) explains that, “[t]here is no way, none, in which a human being could possibly master that [symbolic] world without the aid and assistance of others for, in fact, that world *is* others” (p. 32). Building on this argument, I argue that neither scientists nor science students would make much headway in constructing the sciences without a *means* to collectively share in meaning construction.

Another way to interpret these ideas is that instructors and students co-construct disciplinary knowledge as they engage in discursive social practices as part of a group (Bruffee, 1999). The studio classroom is a learning environment that is designed to foster these discursive social practices among students and instructor(s). Still, maybe the most compelling reason for universities to teach science and engineering disciplines in collaborative learning environments, such as the studio, is that this reflects how the student will function in everyday life (Bruffee, 1999) as a scientist or engineer. After all, scientists and engineers in industry typically work in formal work groups.

Despite the well-known positive attributes of collaborative learning environments and their various forms (Bruffee, 1999), traditional lecture classrooms are still the norm at most universities. Although it might be easy to place blame on college professors for lack of taking personal initiative, Graetz and Goliber (2002) explain that most instructors would most likely prefer to scrap the lecture format and try something else. However, Graetz and Goliber (2002) claim that continued use of the lecture most likely stems from "situational factors, specifically, the absence of support for alternative methods [in the form of training and best practices], the absence of extrinsic incentives to change, and the requirement to use classroom facilities inadequate for supporting collaboration" (Graetz & Goliber, 2002, p. 14). According to the research in organizational behavior, the lecture format traditionally found in college science classrooms is a habitual routine for most science instructors (Gersick & Hackman, 1990). Additionally, research suggests that instructors will default to teaching in the same ways that they learned in their own schooling (Lortie, 1975; Roehrig, Luft, Kurdziel, & Turner, 2003). Undoubtedly, lack of funding for such major changes such as constructing new buildings or remodeling existing classrooms also plays a role. In short, it seems that the traditional lecture and laboratory format persists because there are significant barriers to change: lack of funding for constructing new facilities, lack of widespread faculty initiative for change, and the lack of existing collaborative classrooms that exacerbates an absence of cases showing how instructors design opportunities for learning in these innovative learning environments.

Most research into the studio classroom in the sciences has been based in descriptive studies and/or evaluative assessments in physics (Beichner et al., 2000; Cummings et al., 1999; Saul, Deardoff, Allain, & Beichner, 2000) and chemistry

(Apple & Cutler, 1999; Bailey et al., 2000; Gottfried et al., 2007; Schultz, 2000). Although some evaluative assessments into the effectiveness of the studio environment have been compelling, there is scant literature that provides research-based recommendations for best teaching practices or considerations beyond self reported observations within the undergraduate general chemistry context (Bailey et al., 2000). Although these first hand experiences offer techniques that might be helpful to others, it is unlikely that a collection of best practices (techniques) alone will provide a framework that will impact future design of curriculum and instruction (Weade, 1987) in these types of learning environments. Rather, what is needed is a theoretical grounded model that includes curricular, instructional, and classroom design considerations based in studies of the everyday practices in science-based studio classrooms. However, there are no known studies that empirically examine what is happening in studio classrooms (i.e., how and in what ways instructors and students structure their environment to co-construct disciplinary knowledge).

In designing environments for instruction, a critical goal, especially in the sciences and engineering, is to foster an environment where students have opportunities for learning problem solving practices (NRC, 2012a). As such, it is important to understand how and in what ways learning environments, such as the studio classroom, afford and/or constrain these opportunities. In this way, this study addresses a call for research "to understand how people learn the concepts, practices, and ways of thinking of science and engineering" (NRC, 2012a), one of the long-term goals of Discipline Based Education Research, an interdisciplinary research effort that combines scientist and engineer expertise with learning theories and methods.

Exploring how people learn concepts and practices requires studying people as they construct everyday life, in this case, a tenured chemistry professor and 68 undergraduate engineering students in daily classroom life of a General Chemistry for Engineering Majors course in a studio learning environment. To this end, I adopted an ethnographic perspective (Green, Dixon, & Zaharlick, 2003) as theory and method in order to trace opportunities for learning concepts and practices over time. Foundational to this methodology is a contrastive perspective that makes visible how actors constructed meaning as well as distinguishes between traditional and innovative learning environments, "using" versus "applying" in problem solving, and "successful" and "challenged" student groups.

The primary source of interpreting meaning is through discourse. The means by which participants co-construct a domain of knowledge such as chemistry, is largely discursive, through language-in-use—meaning constructed by language in the context of how language is used to “do something”. Therefore, I consider science to be a discursive practice in this study.

Science conceptualized as a discursive practice was introduced through Lemke’s (1990) seminal work and further developed in the research of Roth and Kelly. By studying how scientific language develops in secondary physics classrooms, Roth showed how gesturing and science artifacts serve as mediating elements that begin to bridge student everyday language towards a scientific language (Roth & Wetzel, 2001). Roth (1996) contends that in learning science, students need to be provided with specific types of opportunities to talk science using the cultural tools of the discipline to mediate the talk towards more legitimate ways of talking. Figure 4 is my visual representation of Roth's conception of how students' everyday talk develops towards more legitimate ways of talking science through deliberately structured activity, instructor talk, and student experience with phenomena of the physical world (or computer simulated microworld). A key component of Roth's conceptual framework is interpretive flexibility which he has repeatedly invoked in much of his work (Roth, 1996; Roth, McGinn, & Bowen, 1996). Interpretive flexibility is the finding that objects and events have "flexible" ontology as students engage with science practices in the process of learning (Roth et al., 1996). This is a process of reconciling the way that students talk about a science phenomena with what they experience (science phenomena) and instructor talk about the phenomena. In this way, the options that students can use to talk about (or explain) a phenomenon are funneled or limited within or towards acceptable new discursive forms of the classroom.

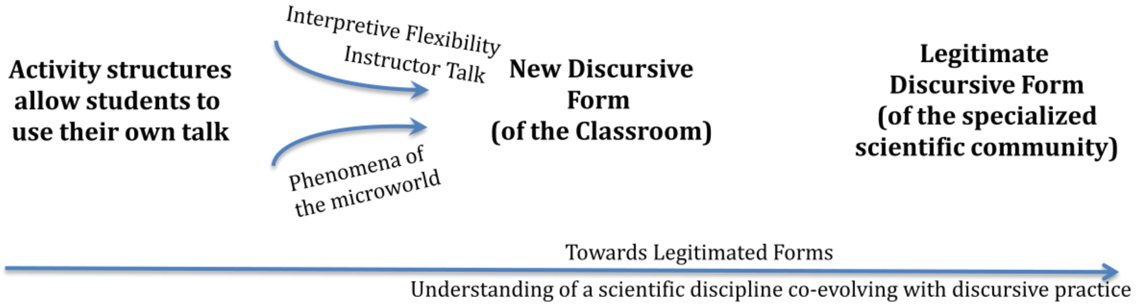


Figure 4. Representation of Roth's conception (Roth, 1996) of how understanding co-evolves with discursive practice towards legitimate forms.

Additionally, he showed how physical arrangements and social configurations within class activities enable or constrain opportunities for talking science (Roth, McGinn, Woszczyna, & Boutonne, 1999) through layered representations of discourse (transcripts) and gestures, physical arrangements, and social configurations (drawings). Although Roth has given more weight to the importance of discourse in more recent work (Roth, 2005, 2010), most of his work has been based in collective activity as the unit of analysis.

On the other hand, other researchers, such as Kelly (Kelly, 2008), ground work in discourse within a sociolinguistic tradition (i.e. language-in-use) studied within an ethnographic perspective as the warrant in the interpretation of collective activity (Kelly & Chen, 1999; Kelly, Crawford, & Green, 1997). Within Kelly's ethnographic and discursive framework applied in the research of science classrooms, learning science means developing new ways of talking and doing science as a process of acculturation into ways of knowing, thinking and acting as a scientist. In this way, the primary unit of analysis is interactions interpreted through discourse (Kelly, 2008) which, in practical terms, is analyzed as collections of related message units (Green & Wallat, 1981). Within this sociocultural perspective of science as taking up scientific ways of knowing, talking, and doing, this frames students as second language learners of a social language of science which has been developed within the scientific community.

This study approaches interpretation of meaning from sociolinguistic and ethnographic traditions as demonstrated by Kelly (Kelly & Chen, 1999; Kelly et al.,

1997) and influenced by Roth (Roth, 1996; Roth, et al., 1996; Roth, et al., 1999) and Lemke (1990). The way that I will use the term “science discourse” in this study includes all the ways and means by which what counts as science, and in this case chemistry, is socially proposed and acknowledged. It includes not just the verbal modality, but also the non-verbal aspect of interactions such as gesturing which has been recognized as having a critical role in developing science talk (Roth & Wetzel, 2001) as well as contributions from artifacts recognized as authoritative references in the discipline, such as the textbook. Contributions from interactions with cultural artifacts, such as digital or analytical instrumentation, may also be a significant element within a science discourse. In the same way, I use the term “discourse” more broadly as any way or means by which a message is proposed and acknowledged in the process of socially accomplishing something (Gee & Green, 1998).

As the first step in a program of research that will impact the designing of spaces for learning that actively engage students in constructing disciplinary content, processes and practices in the sciences, this study explores how the instructor and students structured opportunities for learning problem solving practices. This goal is addressed in a two-phased approach. First, I study the course structuring within the daily events of one undergraduate general chemistry class for engineering majors in a chemistry studio classroom. From an ethnographic perspective (Green et al., 2003), this portion of the study identifies and characterizes the co-constructed activities of the course grounded in the actions and interactions of the instructor and students in order to make visible how the instructor designed opportunities for learning chemistry in this non-traditional learning environment. This phase provides the instructional topology or context.

The second phase of this analysis focuses on exploring the relationship and meanings between two repeated themes in this class, "applying concepts" and "problem solving". Fundamentally, these themes are salient in that problem solving is a critical practice of chemists (and engineers) (Bodner & Herron, 2002). Therefore, how problem solving practices manifest in instruction in this innovative learning environment is of special interest. As such, the goal of this part of the study is to understand how opportunities for learning problem solving practices manifest in the classroom activity of this general chemistry studio. By exploring the relationship between course structuring and problem solving, I make visible how the instructor designed opportunities for learning chemistry and chemistry problem solving practices in this non-traditional learning environment.

Chapter II presents a literature review of history of problem solving research and discusses the conceptual framework detailing the elements of the ethnographic perspective. Chapter III details the methods and methodology used in this study with special attention to the data analysis process and descriptives of the analysis system. Chapters IV and V present data analysis and findings for course structuring and problem solving, respectively. Chapter VI presents a discussion and implications of the findings with limitations and conclusions.

Chapter II: Literature Review and Conceptual Framework

Overview

In this chapter, I locate this study within in the research literature of problem solving. I also present the conceptual framework, based in an ethnographic perspective (Green et al., 2003) which grounds how I approach the methods and methodology (Chapter III) and data analyses (Chapters IV and V) for this study. The last portion of this chapter outlines the research questions.

Literature Review of Problem Solving

Defining terms. Before delving into the complex domain of problem solving, it will be helpful to first define the terms *problem and problem solving, practice and problem solving practice,* and *behavior* and *action.*

Problem and problem solving. Problem solving is foundational in chemistry because it is what chemists *do* (Bodner & Herron, 2002). However, defining problem solving is problematic because it has no one clear meaning (Smith, 1988, as cited in Bodner & Herron, 2002). In one example, “problem” has been defined as: “Whenever there is a gap between where you are now and where you want to be, and you don’t know how to find a way to cross that gap, you have a problem” (Hayes, 1989, p. xii). Also, problem solving has been defined by Wheatley (1984) (as cited in Bodner & Herron, 2002) as: “What you do, when you don’t know what to do”(p. 236). There also seems to be little agreement on models of problem solving in general (Lee & Fensham, 1996; Dewey, 1910, Polya, 1946, Wheatley, 1984, as cited in Bodner & Herron, 2002). Comparisons of these models have been made; yet, the literature suggests that they all seem to oversimplify a complex process that has many more variables than have been proposed by any one model or combination of models (Bodner & Herron, 2002).

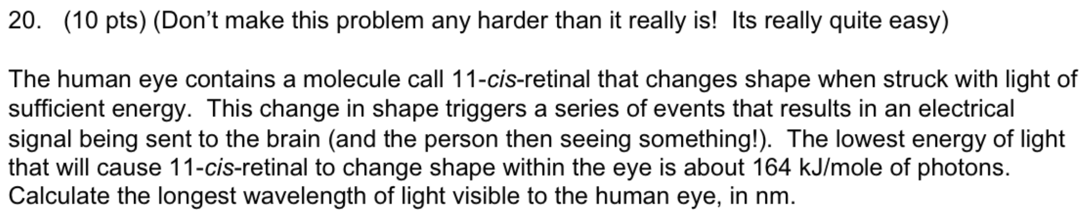
Practice and problem solving practice. If problem solving is fundamental to chemistry, then a goal of the designing of instruction for chemistry (or any science/engineering discipline) in an educational setting, is instilling problem solving practices. The term "practice" is defined as "a habitual or customary performance" (Random House Dictionary of the English Language, 1983). In an educational context, the Framework for K-12 Science Education used the term "practices" rather than "science processes" or "inquiry" skills "to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice" (NRC, 2012b, p. 30). Given these perspectives, a practice could be defined as specific skills performed habitually in and for a disciplinary content area. Within a sociocultural perspective, I also conceptualize practices as ways of knowing, talking and doing in a disciplinary content area. Then, problem solving practices are domain specific practices (ways of knowing, talking and doing) used in the process of resolving or finding a solution to a problem.

Behavior and action. Behavior is defined in psychological terms as "observable activity in a human or animal" and "the aggregate of responses to internal and external stimuli" (Random House Dictionary of the English Language, 1983). Action is significantly different than behavior in that action is "an act that one consciously wills and that may be characterized by physical and mental activity"

(Random House Dictionary of the English Language, 1983). Distinguishing between behavior and action is important for this study because they implicate the methodologies in the conceptual framework. Namely, studying behavior, common in behaviorist and cognitive perspectives, imposes meaning from the researchers' perspective often categorizing observable and quantifiable behavioral events by correlating meaning with frequency of the behavior. Studying action in a sociocultural perspective holds the researcher accountable to warranting meaning from participant interactions with others or cultural artifacts. This study is concerned with studying action as interpreting meaning through interactions, specifically, how and in what ways actors hold each other accountable in constructing culturally appropriate ways of knowing, thinking and doing.

Research in problem solving. Without a clear definition or model for problem solving, researchers have approached problem solving in chemistry and physics in alternative ways most of which are informed by a cognitive (or psychological) perspective. Seminal work in problem solving tried to operationalize cognitive functions from visible behaviors (Newell & Simon, 1972). This work furthered developments in artificial intelligence and contributed to developing the field of cognitive science as the integration of cognitive psychology and computer science (Ericsson, Charness, Feltovich, & Hoffman, 2006).

Still, recent research in problem solving remains well entrenched in cognitive frameworks. Jonassen (2012) framed problem solving as different strategies for solving different problem types based in research that shows that graduate students approach problems in ways that are characteristic of their disciplinary fields. Jonassen (2012) proposes that there are 17 different kinds of problems such as case studies, story problems, trouble shooting and design problems to name a few. These problem types vary along a spectrum from well-structured to ill-structured. Well-structured problems (see Figure 5 for an example) are usually found in education settings where all of the information needed to solve the problem is included in the problem. Ill-structured problems, on the other hand, are those found in everyday life, such as in daily decision making and at work. For example, ill-structured problems include scheduling meals for the week, designing a car, or maximizing efficiency of a process. In ill-structured problems, problem elements may not be known with a high degree of certainty (Wood, 1983). Solutions are usually interdisciplinary and require integration of several content area domains. Ill-structured problems may also have multiple solutions, solution paths or no solution (Kitchner, 1983) and may be subject to personal values and moral judgments. Although information-processing theories



20. (10 pts) (Don’t make this problem any harder than it really is! Its really quite easy)

The human eye contains a molecule call 11-*cis*-retinal that changes shape when struck with light of sufficient energy. This change in shape triggers a series of events that results in an electrical signal being sent to the brain (and the person then seeing something!). The lowest energy of light that will cause 11-*cis*-retinal to change shape within the eye is about 164 kJ/mole of photons. Calculate the longest wavelength of light visible to the human eye, in nm.

Figure 5. Example of a well-structured problem from Exam 2 in the course under study. This is also an example of a story problem.

have claimed that the processes required to solve ill-structured versus well-structured problems are similar (Simon, 1978), more recent work (Allaire & Marsiske, 2002; Hong, Jonassen, and McGee, 2003; Jonassen & Kwon, 2001) suggests that "well-structured and ill-structured problem solving engage substantively different cognitive processes" (Jonassen, 2012, p. 8).

This study is concerned with two types of problems: algorithmic-based and story problems. Both are well-structured problems with single solutions. Most common in mathematics courses, algorithmic problems involve a rigid set of procedures, usually as calculations, to get to a single solution. Story problems are much like algorithmic-based problems with the exception that the salient information is woven into a story or situational format like that shown in Figure 5. Methods for solving story problems identified in past research include: representing the unknown(s) as variables, translating relationships between unknown(s) one or more equations, solving the equation(s) to find the values of the unknown(s), and verifying that the solution meets the requirements of the problem (Rich, 1960, as cited in Jonassen, 2012). A critique of both algorithmic and story problem types from past research is that students tend to memorize the linear solution paths which leaves them unable to apply the underlying concepts to new contexts (Woods, Hrymak, Marshall, Wood, Crowe, Hoffman et al., 2007) because "they fail to understand the principles and the conceptual applications underlying the performance" (Jonassen, 2012, p. 14).

Problem solving in the physical sciences. With the development of a cognitive science framework, most of research in education with regards to problem solving was cast within a new “goal” of education–developing expert cognition (Feltovich, Prietula, & Ericsson, 2006) by distinguishing between “expert” and “novice” problem solving behaviors (Chi, Glaser, & Rees, 1982). With regards to problem solving in the physical sciences, much of the research in distinguishing novices and expert ways of problem solving in the sciences set up dichotomous comparisons between instructors and undergraduate students (Chi, Feltovich, & Glaser, 1981; Larkin, McDermott, Simon, & Simon, 1980). In one of these studies, experts and novices were asked to group problems by way in which they would go about solving the problem (Chi et al., 1981). Experts created groups based on major disciplinary principles, such as conservation of energy, that they would use to solve the problem. Novices grouped based on the physical objects in the problem such as springs or inclined planes. However, in creating expert and novice groups by comparing Ph.D. instructors and undergraduate students, the desired outcomes between expert and novice may be lost to a comparison “between the performance of experts working routine exercises and the performance of novices working novel problems” (Bodner & Herron, 2002, p. 240). In other words, the functional meanings for “problem solving” already mentioned suggest a subtle difference between an “exercise” and a true “problem” based in the relationship to the person providing (or attempting to provide) a solution (Bodner & Herron, 2002). The problem becomes an “exercise” when the person solving the problem knows how to solve it. In this way, “problems” for students are usually routine “exercises” for instructors.

In response to this critique, other study designs have compared the performance of “expert” students and “novice” students in chemistry based in either a priori honors versus regular class designation (Kumar, 1993) or designating students as experts or novices based in their performance on an assessment and generalizing the group problem solving characteristics thereafter (Heyworth, 1999). Reflecting on similar findings of the professor and student studies, Heyworth (1999) noted that there is a fundamental difference in the way expert and novice students approach problem solving. The experts worked in a forward step-by-step strategy while novices used a “means-end” strategy. Approaching problems with a forward strategy suggests that these students were guided by recognizing the disciplinary concepts applicable in the problem or by a conceptual understanding of the problem. The “means-end” strategy consists of identifying the known and unknown variables in the problem and finding a mathematical formula that matches the variables or that will provide a solution in the required units. In other words, novice problem solvers knew what the end state should look like and worked towards those ends. These strategies, although studied in the context of chemistry, is equally applicable to other science and engineering disciplines.

In another model, Smith and Good (1984) (as cited in Bodner & Herron, 2002) suggest that this “expert/novice” distinction does not exist as a dichotomy but rather a spectrum of successful/unsuccessful problems solvers. In one of the most recognized studies involving problem solving behaviors in chemistry, Camacho and Good (1989) used problem solving performance as a continuum to show that successful and unsuccessful problem solvers exhibit markedly different behaviors in solving chemical equilibrium problems. Much of their findings resembled those found in previous expert/novice models.

In addition to reviewing the research in expert/novice and successful/unsuccessful problem solving behaviors in chemistry and physics, it is not always clear to what extent researchers are linking ability to solve an algorithmic-based problem with as student's conceptual understanding of the problem. Even in most entry-level undergraduate physical science and engineering courses, demonstrating proficiency in the discipline means being able to apply disciplinary concepts as mathematical relationships or equations. This suggests an implicit assumption in some undergraduate science courses that being able to do a problem quantitatively is synonymous with understanding the problem conceptually.

This assumption was challenged directly in research in an undergraduate general chemistry course suggesting that students who could solve quantitative (mathematically based) problems could not necessarily answer a similar qualitative (conceptually based) problem (Nurrenburn & Pickering, 1987). In other words, being able to do a quantitative problem does not mean that students necessarily understand the problem at a conceptual (qualitative) level. Similar experiments show that this effect could be seen in both higher and lower achievers in an otherwise homogeneous group (Sawrey, 1990). Other research studied where this effect could be attributed to differences in student ability or student gaps in knowledge (Pickering, 1990). These findings suggest that there are not two types of students (conceptual or mathematical) but rather two types of instructional goals (conceptual or mathematical) and that these goals are independent of each other. In other research, direct comparisons between a physics studio and traditional (separate lab and lecture) learning environments suggest that if students are expected to be proficient in both conceptual understanding and algorithmic problem solving, then both must be explicitly taught (Hoellwarth, Moelter, & Knight, 2005).

So assuming that expectations for mastery of content means that a student must be able to apply disciplinary concepts to solve problems in various contexts within the domain, research in expert/novice and successful/unsuccessful strategies offers little guidance in designing opportunities for learning that would foster such outcomes. In fact, Bodner and Herron (2002) point out that the behaviors touted in the expert/novice or successful/unsuccessful dichotomies should not be used as guidelines to teach students how to solve problems. Rather, they suggest that

> …as one gains expertise in a field, one is able to formulate better representations of the problems encountered and is less dependent on general, inexact strategies [such as means-end] to solve them. Problems metamorphose into exercises, and students are more successful because they have more declarative knowledge to work with. (p. 242)

Developing Expertise. Performance in problem solving improves as one gains expertise in the field (Bodner & Herron, 2002). Therefore, the research in how people develop expertise is especially salient for this study. Expertise refers to the "characteristics, skills, and knowledge that distinguish experts from novices and less experienced people" while expert performances refers to "types of superior reproducible performances of representative tasks [that] capture the essence of the respective domains" (Ericsson, Charness, Feltovich, & Hoffman, 2006, p. 3). Much of the research in expertise and expert performance has contributed to generalizable characteristics of expertise and their theoretical mechanisms. These characteristics include: expertise involves larger and more integrated cognitive units; expertise is limited in its scope and elite performance does not transfer; and expertise involves selective access of relevant information (Feltovich et al., 2006). Additionally, the research suggests that disciplinary content knowledge is considered a critical part of the cognitive process (Newell & Simon, 1972) and essential in developing expertise (Feltovich et al., 2006).

One of the more recent and prominent methods in providing opportunities for learning that developed from research in how people develop expertise is problem based learning (PBL). Predominant in the medical field but also found in math and science classrooms, PBL affords students the opportunity to engage in ill-structured types of problems which students analyze in small groups supported by a more experienced tutor. In engaging with these authentic problems, students recognize gaps in their own knowledge which gives them opportunities to frame their own goals in learning and initiates a need to obtain the knowledge through material resources or from more experienced personnel. Typical PBL sessions are held two or three times a week where one day is dedicated to problem analysis and learning goal identification and another for presentation of solutions and lessons learned (Boshuizen, 2006).

Moving from individual behaviors to cultural practices. Clearly, a cognitive perspective informs much of the research in problem solving, but these are not without critique. As I have shown here, this work characterizes problem solving as behavioral outcomes of a problem solving process. However, this perspective does not address how students develop these practices. Additionally, Leach and Scott (2003) question the practicality of a cognitive perspective in the studies of teaching and learning in educational settings,

> In our view, it is not feasible for teachers to plan instruction to address each student's momentary and individual development. In order for research to inform science teaching, it is necessary to theorize the relationship between teaching and learning rather than focusing upon individuals with no reference to the learning environment. Addressing these types of questions requires moving from conceptions of knowledge as being created in the student's head to knowledge being constructed in the social world then being made accessible to students. (p. 95)

Additionally, Lemke (1993) questions the conceptual basis of a cognitive perspective,

> If it is useful to formulate a notion such as cognition at all, we must never forget that cognition, the act of making meaning, is always a bodily and interactive process, dependent on tools, on environmental affordances and feedback (re-afference), on situational context, and most profoundly on

> internalized patterns of originally external, and especially social, culturally and symbolically mediated, interaction. It is this "inter-activity" in and through which we live, make sense of and to others and the world, learn, and do science.

To address how students develop problem solving practices, I move from conceptions of knowledge as being created in the student's head to knowledge being constructed in the social world then being made accessible to students who then draw on this knowledge to reformulate it for themselves.

This study adopts a sociocultural perspective of learning which has been developed in psychology (e.g. Vygotsky, 1978; Luria, 1976), in anthropology (e.g. Malinowksi, 1935; Geertz, 1973, 1983), in sociolinguistics (e.g. Gumperz, 1997; Hymes, 1972) and philosophy of language (e.g. Bakhtin, 1986) and extends these epistemologies to problem solving. Gaining expertise in science or any other domain necessarily involves taking up the cultural and social conventions of the discipline through social, culturally and symbolically mediated interaction. In this study, these are located in opportunities for doing problem solving in an undergraduate general chemistry course within a studio learning environment.

This study contributes to what we know about how students acquire disciplinary content knowledge, specifically, problem solving practices within a sociocultural perspective. Here, opportunities for learning the practices of “problem solving” of a domain is a process of positioning a learner to engage with and take up a social system of resources such as "language, gesture, depiction, symbolic representation, and the meanings of actions" (Lemke, 1993). In this way, this social system is characterized by normalized ways of knowing, talking, and doing within the domain towards an outcome that counts as a "solution" in the domain (or moving towards developing disciplinary expertise).

Conceptual Framework

Overview. In order to study the naturally occurring patterned processes and practices in classrooms for both course structuring and problem solving, I adopt an ethnographic perspective. Ethnography has been recognized by the science education community as an empirically-based research practice (NRC, 2002) and has been used in various industries to study cultural practices in everyday life. The actual practice of studying processes and practices in everyday life involves negotiating through what most would consider to be a series of complex and interacting systems imbued with social issues, culture, and language. So before I discuss what I *do* when taking up this work, I establish a set of conceptually guided principles which form an "analytical lens" by which a researcher can make methodological decisions for records gathering and then making sense of and negotiating a route through the milieu of available information. In this way, taking up an ethnographic perspective is taking up an epistemology (Agar, 2006; Anderson-Levitt, 2006; Green, Skukauskaite, & Baker, 2012). This requires a clearly defined conceptual framework.

This conceptual framework is comprised of orienting theories and an interpretation of their meanings and relationships that, as a whole, inform my logic of inquiry through which I conduct ethnographic research. In this section, I present my logic of inquiry as my roadmap based in ontological understandings (beliefs about how the world works) and epistemological theories (origins of knowledge) that will remain constant during all research processes and provide the foundation to guide or orient all decisions within the processes. I then provide a conceptualization of the classroom within these foundational understandings in order to frame how disciplinary content is being made present to students in the moments of instruction.

My framework conceptualizes reality as socially constructed. Here, I draw from Vygotskian theories of what he calls “scientific concepts” as those abstract frameworks learned systematically from interactions with others and/or through experience with the world (Vygotsky, 1978). In this way, people learn about the world through their interactions with socially constructed cultural practices which changes the individual and, in the process of interaction, also changes the cultural practice. This dynamic dialectical process (Hegel, 1977) is the basis of my conceptualization of how we come to understand the world. From this start point, I then assume an ethnographic perspective to study cultural groups in their everyday experiences.

Ethnographic perspective. Grounded in social constructionism within an ethnographic perspective, I take up the view of ethnography as the study of cultural practices as entailing a contrastive perspective and a holistic perspective as proposed in Green et al. (2003). In addition, a significant component of my conceptual includes language as a social practice as influenced by Gumperz (1997), Gumperz and Cook-Gumperz (2006), Hymes (1972; 1977), and Bakhtin (1986).

But, first, in defining culture, I draw on the work of cognitive anthropology (Goodenough, 1981; Spradley, 1980) which views culture as socially patterned actions. Participants come to understand accepted roles, relationships, rules and obligations of the group by experiencing how things are done within the group. In other words, in learning who can do what with whom, under what conditions, when, for what purpose and with what outcome, participants learn what is required to participate as a member in the social group (Green & Meyer, 1991). Still, the dialectical process involved in any interaction implicates the member as part of the process of co-constructing roles, relationships, norms and obligations as he or she negotiates them. In the same way and within the context of educational spaces within an ethnographic perspective, Heras (1994) maintains that classrooms are lived and shared spaces for co-construction of learning:

> The range of lived opportunities, possibilities and constraints opened up in classrooms and schools depends on the configurations made possible by the institutional organization of the school and classroom and by the social and academic interactions constructed within these institutional spaces. From this perspective, knowledge is related to the real or actual opportunities members of a group have and construct as they engage each other in and through the events of everyday life within a classroom (p. 277).

In this way, I conceptualize the purpose of the educational endeavor as providing an *opportunity for learning* (Tuyay, Jennings, & Dixon, 1995) within a cultural group brought together to engage in common and socially co-constructed practices for this common purpose.

By conceptualizing ethnography as the study of cultural practices (Green et al., 2003) within a socially constructed view (Vygotsky, 1978; Agar, 2006), cultural practices must be studied with respect to the situations and conditions under which they transpire. In other words, cultural practices are situated (Heap, 1991). A situated perspective of cultural practice is a significant part of my conceptual framework that addresses how to infer meaning within cultural practices. Heap (1991) proposed elements of a situated perspective that have provided a framework for me to locate where culture may be made visible and to understand constraints in inferring meaning within this perspective. These elements include: phenomenological conception of consciousness, adoption of the actors' point of view (or emic perspective) and language as constraining meaning. The phenomenological conception of consciousness contends that actors act intentionally. This assumption is critical to the argument for ethnographic perspective because the basis of evidence is the actions of actors. Without this assumption of an actor who acts consciously (with intention), then meaning could not be inferred through their actions. If the researcher assumes that actors act intentionally, then to infer the meaning of an act, the researcher must take the point of view of the actor. In this way, the conceptions of consciousness and the emic perspective are intimately related.

The last element of a situated perspective is that language constrains meaning. According to Heap (1991),

> What counts as reading, error, or any object is not merely a matter of individual interpretation. It is not arbitrary, unconstrained. The constraint is language. The ordinary language philosophers, and later Wittgenstein (1958) in particular, have written extensively and persuasively on the nature of language as a social, historical, situated set of constraints on (and resources for) what anyone can mean by saying something (p. 122-123).

Within Heap's (1991) conception of how language constrains meaning, in a situated perspective, an ethnographer must take an emic perspective considering the actor's view of an event within the framework their linguistic history (experience) with a specified type of event.

Another principle central to my conceptual framework in how to approach ethnographic work is use of a contrastive perspective based in Hymes' (1977) concept of contrastive relevance. Contrastive relevance can be understood in the context of Agar's (2006) claim that culture is relational, "Culture becomes visible only when differences appear with reference to a newcomer, an outsider who comes into contact with it" (p. 5). In this way, contrastive relevance can be used as a methodological strategy for identifying norms and obligations, roles and relationships and rules and obligations as newcomers to a group negotiate what is acceptable and not acceptable for the cultural group within the situated event under study. In these situations where a newcomer does not understand what is happening, Agar (1995) drew on Mehan's (1979) "frame clash." Frame clashes provide an opportunity for the newcomer (or researcher) to explore the understandings or interpretation of the insider in what Agar

(1995) calls a “rich point” (p. 141). The concept of contrastive relevance also guides in identifying event boundaries where moment-to-moment collective actions to include language use signal that a different cultural event is taking place. In addition, understanding the scope of the contrastive perspective is especially critical in study design where selecting opportunities for collecting data records that are inherently (and naturally) contrastive would most effectively set conditions for difference recognition. So when comparing otherwise similar groups, differences in action and/or discourse practices (frame clashes) provide opportunities to learn about the cultural features of a group. In this way, the contrastive perspective is not simply a method or strategy. Rather, it implicates conceptual understandings about how actors learn through and contribute to a cultural group.

If, in using a contrastive perspective, we look across actors, actions, times and events, then we are in effect taking a holistic perspective. Within a holistic perspective, phenomena must be examined within all the spaces (time, space, text, action) it exists. Taking up a holistic perspective requires consideration of different levels of analysis to approach the phenomena from different angles as well as identifying and showing whole-part relationships between actors, events, times and spaces (Green et al., 2003). Implications for study planning include the argument that the ethnographer should try to collect records from as many pertinent sources (text, discourse, artifacts) as possible and with the means (video, audio, field notes, interviews) that might facilitate the warranting of possible meanings and /or substantiate inferences through triangulation.

Although studying cultural practices using contrastive and holistic perspectives does consider language within this framework as a communicative act, language is so infused with culture and culture is so intimately inscribed within language practice that an argument framed by Agar (2006) conceptualizes language as "languaculture". In addition, I further integrate language theories in the traditions of interactional sociolinguistics (Gumperz & Cook-Gumperz, 2006) and ethnography of communication (Hymes, 1972) into my logic of inquiry as the conceptual basis for discursive practice in inferring meaning. These closely related traditions bring theories about how people gain fluency in being able to recognize and participate in various sociocultural systems through language use.

Hymes (1972) argues that as people gain communicative competence, they expand their linguistic repertoire (Gumperz & Cook-Gumperz, 2008). Based on this, I assume that actors make choices of which language style to use from their available linguistic repertoire. In addition, I assume that the actors make action (including discursive) choices based on their understanding of the sociocultural system in which they find themselves and the ways in which they chose to position themselves within that system. It is within these assumptions that I conceptualize language as a sociocultural practice. In this way, interactional sociolinguistics and ethnography of communication recognize that actors bring sociocultural histories as knowledge obtained from prior situations and consider how these influence understandings (meanings) to the event under study, which will, in turn, influence what is, will, and can occur (Gumperz & Cook-Gumperz, 2006). Therefore, discourse must be studied with respect to the meaning constituted within it.

To infer meaning, I also draw on Bakhtin’s (1986) conception of the implicated hearer such that meaning cannot just be inferred by only the utterance of the speaker, but in the way the hearer responds to the utterance. This concept is similar to those previously discussed with regard to actions–meaning can only be inferred with respect to the conditions under which the act (speech act or utterance) is situated. Therefore, the researcher must analyze the discourse at the interaction sequence levels for patterns signaling what the interaction is about (Gumperz & Cook-Gumperz, 2006). These patterns in activity, which include in significant changes in action as signaled by contextualization cues (Gumperz & Berenz, 1993), can provide an analytic basis for identifying and assisting in bounding events.

This study is grounded within this conceptual framework, the logic of inquiry, based in epistemological understandings of cultural practices from anthropology as situated, constrastive, and holistic (Agar, 2006; Green et al., 2003; Heap, 1991) as well as understandings of language from sociolinguistic traditions (Bahktin, 1986; Gumperz & Cook-Gumperz, 2006, 2008; Hymes, 1972, 1977) as a sociocultural practice.   This conceptual base extends into framing science as a discursive practice as developed by Lemke (1990), Roth (2005, 2010), and Kelly (2008).

Research Questions

In order to study how problem solving practices are proposed and taken up by students in this studio learning environment, I approach this study in two major phases: course structuring and problem solving.

Phase 1. I first conducted a detailed descriptive analysis of how this course functions based on the actions and interactions that instructors and students use to co-construct everyday events. The overarching question in this phase was: How does this undergraduate general chemistry class function in the daily processes and practices within a chemistry studio learning environment? In this phase, each of two major exam cycles of activity were analyzed separately and constitute Research Questions 1 and 2, respectively. This phase characterizes the course structuring which is the environmental context for the next phase, analysis of problem solving.

Phase 2. The second phase of this study drew on the course structuring elements made visible in addressing Questions 1 and 2 to show how the opportunities for learning problem solving practices were proposed and taken up by students. Based on what was required for students to complete a select portion of the second exam, this phase traces how the instructor positioned problem solving from the first class day, through the constructing of the select disciplinary content and practices in events and activity, to the exam which occurred at the beginning of Week 7 of the class. Then, still within the same disciplinary content, I refocused the analytical lens from the collective (whole class) to a studio table group in order to examine how and in what ways students constructed opportunities for learning how to use or apply concepts. The overarching question for this analysis of problem solving processes was: Within this studio learning environment, how are problem solving practices proposed and taken up by students? The initiating question based in the anchoring element was: How and in what ways do participants construct opportunities for learning how to use or apply concepts in this course?

Research questions for Phase 1 (Questions 1 and 2) and Phase 2 (Questions 3, 4, and 5) are as follows:

Research Question 1. How did this undergraduate general chemistry class function in the daily processes and practices within the **first** exam cycle of activity?

Question 1a. In what ways was time spent in collective activity?

Question 1b. What were the key events in this course and how are they characterized?

Question 1c. In what ways did the key structuring features of the course make visible principles of designing this course?

Question 1d. In what ways were lecture and lab "integrated" in this chemistry studio?

Research Question 2. How did participants structure daily practices and processes in the **second** exam cycle of activity in comparison to the first exam cycle of activity?

Question 2a. In what ways was time spent in collective activity in the second exam cycle of activity?

Question 2b. In what ways did collective activity in the second exam cycle of activity contribute to how key events and activities were characterized?

Question 2c. In what ways did the patterns in events and activity in the second exam cycle of activity make visible principles of designing the course?

Research Question 3. In what ways did the instructor frame (or position) problem solving in course documents and introductory comments in the course?

Research Question 4. In what ways was select disciplinary content proposed and negotiated by participants over time in collective activity?

Research Question 5. In what ways did students construct opportunities for learning how to use or apply concepts for the selected disciplinary content (in Question 4) within lab-partnered group and table interactional spaces?

Chapter III: Methodology and Methods

Overview

The purpose of this chapter is to provide an account of how this research was conceived, planned and conducted. Grounded in the logic of inquiry presented in the previous chapter, methodology refers to “the integration of theoretical and methodological issues” and method refers to the “techniques, tactics, and strategies of data collection, analysis, and reporting” as discussed by Bloome, Carter, Christian, Otto, and Shuart-Faris (2010, p. xviii). To be clear, references to methodology implicate theoretical issues as they influence decisions about and in the conduct of method(s).

In this chapter, I first situate the study in the context of this chemistry studio classroom, the course, and study participants. Then I show methods for the collection of all record gathering functions (videotaping, interviews, field notes, and collected artifacts) followed by a detailed discussion of the principles that guided data analysis based in the conceptual framework. For purposes of this section, "records" are the video and audio representations of what could be seen and heard from vantage point of the video camera and audio device(s). This is equivalent to what the sciences may call "raw data". Here, the term "data" is defined as a representation of selected records constructed with a specific purpose or to answer a specific question. The exception to the use of this terminology are references to "data" in this specific disciplinary context where the students acquiring "data", not "records", in a chemistry laboratory activity is a culturally normalized term in the discipline.

Context

This studio. During records collection at the research site, a chemistry studio classroom at one leading 4-year undergraduate university in California, a new complex of classrooms all based in the studio design was being constructed. Even without an off-the-shelf studio-based general chemistry curriculum (a commercially available studio chemistry curriculum does not exist), ten years of using this chemistry studio classroom as well as other similar classrooms in math and physics at this university compelled the institution to build more like it. Upon completion of the new classroom complex in 2013, all general chemistry classes will be held in a chemistry studio (Bush, personal communication, October 10, 2010). This means that approximately ten chemistry professors will transition from teaching a traditional lecture course separate from the lab to a studio classroom in academic years 2012 and 2013.

The chemistry studio at this institution (see Figure 3, page 6) was constructed in 1994 within a building of classrooms designated for instruction in the mathematics and the sciences. It was constructed by knocking down a wall between two smaller classrooms (Bailey et al., 2000). As a result, the room is almost three times as long as it is wide (See Figure 6). Online resources refer to the General Chemistry course in this classroom as “integrated lab and lecture” focusing on the main physical characteristic of the studio. Characterizing *how* these functions are “integrated” is one objective of this study. Aside from having both laboratory and lecture functions occurring within the same time and space, the other key feature of

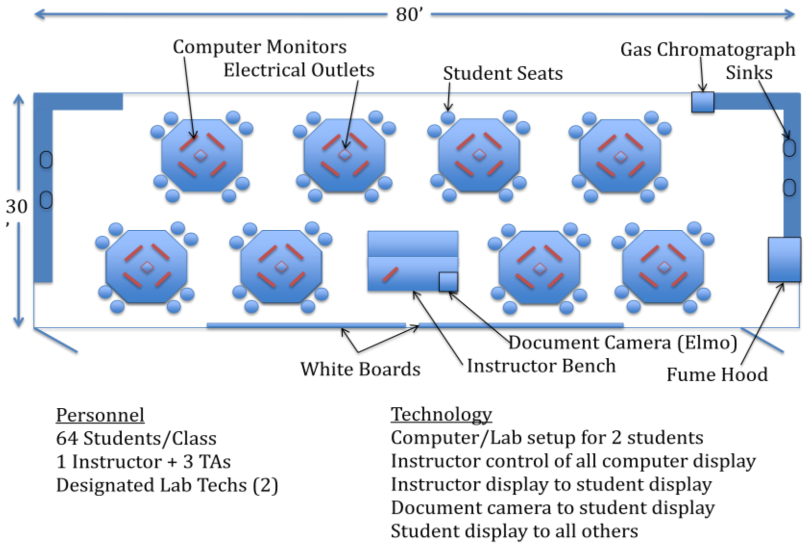


Figure 6. Site map of the chemistry studio classroom under study with personnel and technological capabilities.

this classroom is that rather than sitting in rows facing the instructor, students sit in circular eight person groups. Designed for seating 64 students at eight circular modular tables, the eight person groups are referred to as a "table" or "table group". Each group of eight students are further divided into four groups of two and designated as "lab partners." The area occupied by lab partners is a "bench" (carryover from traditional laboratory terminology). The instructor's area is also called a "bench." Each circular table houses four computers, one for each of the four lab partnered groups. In the center of the classroom, the instructor bench has a desktop computer with monitor and a document camera which this instructor called "Elmo".

In this chemistry studio, all student monitors can be controlled from the instructor's bench. The instructor can display what is on her computer or from the document camera or work of one group to all other student computers. Tables and chairs are movable, so classroom layout may be repositioned. However, accessibility to floor electrical outlets, lack of space, and modular design of the tables make design changes impractical. Storage units on the short sides of the classroom provide storage for equipment typically found in a traditional chemistry laboratory such as glassware and basic analytical measurement devices. Material resources allow each lab partnered group to conduct an experiment with their own equipment. The chemistry studio also includes various analytical chemistry equipment such as a spectrometers and a gas chromatograph. Laboratory technicians set up and take down additional required equipment for each laboratory as well as provide support for computer hardware and software. Every computer has a set of Vernier© analytical devices which includes a temperature probe and pH meter. Student computers can also obtain data from the gas chromatograph in the classroom through Logger Pro©. Teaching assistants (TAs), who are upper level chemistry or engineering undergraduates, guide groups of students in using unfamiliar equipment.

The course. The General Chemistry for Engineering Majors course is a required two-quarter sequence for all engineering majors. The course under study is the first in the sequence. It covers the same topics as a traditional general chemistry course with the inclusion of the additional topics of solid-state chemistry and materials and an introduction to organic chemistry. The course disciplinary content is shown over the ten-week period in the Data Analysis section. Among the Department of Chemistry faculty, General Chemistry for Engineering Majors is considered a service course because it services students who are not science majors. As such, most instructors in this course are hired as lecturers allowing the tenure track faculty to focus on the science majors (Neff, personal communication, February 25, 2011). At the time of this study, this chemistry studio was the only one of its kind at this institution so its use was very limited. As a result, only the first quarter course of the two-quarter General Chemistry for Engineers sequence was taught in this classroom.

With only one chemistry studio, if more sections of the course are required in an academic quarter than can fit in the time schedule of the chemistry studio, additional sections were taught in the traditional way, a separated lecture and laboratory (Neff, personal communication, June 6, 2012). With this in mind, at this institution, the official curriculum (Posner, 2004) supports both kinds of courses, the studio and the traditional. In both cases, the course topics, textbook, web-based resources, and laboratory experiments are essentially the same.

Participants. Participants in this study include the researcher, instructor, teaching assistants (TAs) and students.

Researcher. As a researcher, I bring content knowledge in chemistry (M.S.) and chemical engineering (B.S.). In addition, I have taught General Chemistry at the undergraduate level for three years using an earlier edition of one of the two textbooks (Silberberg, 2009) that were recommended as references in the General Chemistry for Engineers course. Of primary consideration for me as an ethnographer was to be aware of the presuppositions that I brought with me from my prior experience as an instructor in this content area. However, I had no prior experience with studio-type classrooms. I entered the research site as an observer and did not engage with the students in other than a research capacity.

Instructor. The instructor, Professor N, is a tenured professor in the Department of Chemistry at this institution. She had been teaching General Chemistry for engineering majors for ten years in this chemistry studio and she had been the course supervisor for the prior six years. Prior to coming to this institution, she taught general chemistry for engineering students at another four-year state technical university in California in the traditional lecture and laboratory settings. At the time of this study, this professor was teaching both General Chemistry for Engineering Majors and a physical science course, taught in different studio classrooms. This professor was selected as the instructor for this study because she was teaching these two different courses, both within two different of studio classroom environments, during the same academic period. It is important to note here that this study focuses only on the chemistry studio within the General Chemistry for Engineering Majors course.

Teaching assistants (TAs). There were three teaching assistants for this class. All were undergraduates as this institution has few graduate programs. One male TA, chemistry major, conducted weekly tutoring sessions outside of the formal class time as part of the institution’s program to provide an additional resource for assistance in courses that are known to be challenging for students. Two female TAs, both engineering majors, assisted in grading and monitoring student progress in workbook problem sessions and labs.

Students. This General Chemistry for Engineering Majors course consists of sixty-eight, mostly first year engineering students. Because the course is an engineering requirement and seating is limited, the professor admitted four more students than is allowed by classroom design. As a result, four student groups were made up of three students. Of the 68 students in the class, 15 were female. All students were engineering majors, which could include aerospace, biomedical, civil and environmental, computer, computer science and software, electrical, industrial and manufacturing, materials, and mechanical engineering. (http://ceng.calpoly.edu/academic/departments/, accessed May 21, 2012) The most represented majors were civil engineering (19), materials engineering (9), computer engineering (7), electrical engineering (6), mechanical engineering (6) and aerospace engineering (5). Course grades were distributed as shown in Figure 7.

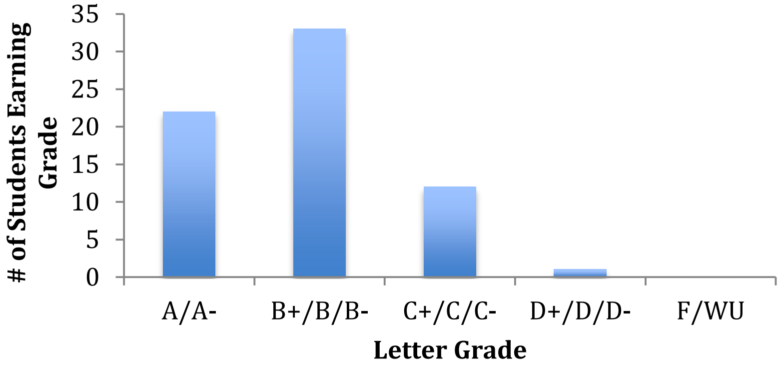


Figure 7. Overall course grade distribution for 68 students in the General Chemistry for Engineering Majors class under study.

Gaining Entry to the Research Site

Negotiating entry to the research site required Professor N's approval for the study concept as well as her consent and the consent of the students and TAs. All students and TAs gave consent. A key element that secured entry to the research site was the assurance that disruption of the class during observations and videotaping would be minimal. This meant that I, as the researcher, would not impose changes to any part of class.

Methods of Records Collection

Four methods were used to obtain records: videotaping of classroom meetings, observations in the form of field notes, ethnographic interviews of the instructor, and collection of course artifacts. This section explains each method with regards to the methodology involved in planning for and using each method.

Video/Audio recordings. I selected video as the primary means of recording classroom happenings because it gave me the flexibility to enter the video as needed (Green et al., 2012) in order to locate information that may explain happenings in other times and spaces and/or trace processes forward and backward in time.

My conceptual framework guided many methodological decisions with regards to the video and audio recordings concerning camera positioning and view, portion of the course to record, and the length of time to record. Two cameras recorded two visual perspectives of each lesson. The primary camera focused on and followed the instructor. However, since interactions are the basis of meaning (Gumperz & Cook-Gumperz, 2006), I needed to record interactions as much as possible. This meant that the angle of vision of the video needed to include those involved in interactions as well as record the discourse in the interaction. To represent collective action the video angle of vision was wide enough so that the instructor and 5-10 students could be seen in the same view. During lecture activities when the instructor controlled student displays, the view included a student monitor so that the relationship between what the instructor said and what was available visually to students on their monitors was visible. In this way, the display and computer was an actor in this study. Also, in order to record all instructor interactions with students, inside and outside of whole class interactional spaces, the instructor was remotely microphoned. Then, in concept, the audio on the primary camera recorded what the instructor said and what was said by others in her immediate vicinity.

The second camera, which had a wider angle capability than the instructor camera, was set to the widest angle possible focused squarely on a table group with as much of the class as possible in the background. Students maintained seating positions for the duration of records collection so group membership remained constant. This table group was selected because they were in the back corner of the room and easily accessible the researcher. This camera angle and view remained constant every day of recording. From the instructor's perspective looking our from the instructor's bench, the cameras were positioned in the back right corner of the classroom for easy access. Video camera positions are shown in Appendix A.

In order to show how cultural practices and processes developed over time, I needed to record enough class meetings where patterns in action could be contrasted for analysis. To this end, I recorded two of three exam cycles in the 10-week course. This encompassed six weeks of recording approximately 60 hours of video. Additionally, because I think cultural practices and processes are often made visible by the instructor during the onset of group formation, I elected to include the first cycle of activity in records collection. For these reasons, the first and second exam cycles comprise the video record archive.

Central to my view of the contribution of video records to this study is the view of video records as a type of field note. As such, video is an actor/partner within the research site (Baker, Green, & Skukauskaite, 2008). It records one perspective of what occurred in the classroom within the boundary of what can be seen and heard and within the experience and theoretical framework of the ethnographer as an analytical lens. In this way, the video also provides a means by which the ethnographer may enter the site repeatedly at later times. In addition, video records provide a "raw" record that may be used as an anchor for analysis at different levels of analytical scale (Baker et al., 2008).

Interviews. In addition to video records during class time, three one-hour interviews with the instructor conducted within the year prior to records collections were also available. I included interviews of the instructor as another method to gather records because it offered another perspective by which I could view the happenings in the classroom. In records collection during the study’s first year, I conducted three ethnographic interviews with the instructor which helped me gather information about the academic history of the instructor and her experience in this studio classroom. All interviews took place in the instructor's office overlooking the construction site for the new science building. The design of interview protocols was based in an ethnographic model (Spradley, 1979) and a standard open-ended interview approach as discussed by Patton (2002). I planned for open ended questions to provide the informant the space for her own voice and meaning to their responses (Brenner, 2006). In this way, protocol design was an iterative process to establish the key descriptive characteristics of this studio environment from the instructor's (emic) perspective. In addition, the protocols could be adapted freely in accordance with the tempo of the interview. The interview as an analytical method gave me the opportunity to explore these characteristics from the perspective of the instructor as a source that I may use as additional evidence (triangulation) to support evidence from my primary source, the video records. In addition, it allowed me to clarify the use of cultural (folk) terms (Spradley, 1979) used in data analysis.

Field notes. During each observation of each class, I took fieldnotes in a bounded notebook. I took field notes with two primary outcomes in mind. First, I used my fieldnotes as the means of recording how I labeled the video records for subsequent archiving for ease in retrieval. Second, I intended to use the fieldnotes to annotate points of interest in the video records as possible rich points (Agar, 2006) in later analysis. Within the fieldnotes I also recorded the positioning of the cameras and noted summaries of conversations I had with the professor during class. In addition, at various times during my observations I sat directly behind the instructor during lecture activities to record what was required of her to conduct a lecture event as well as experience what could be seen and heard from her visual perspective during lecture periods.

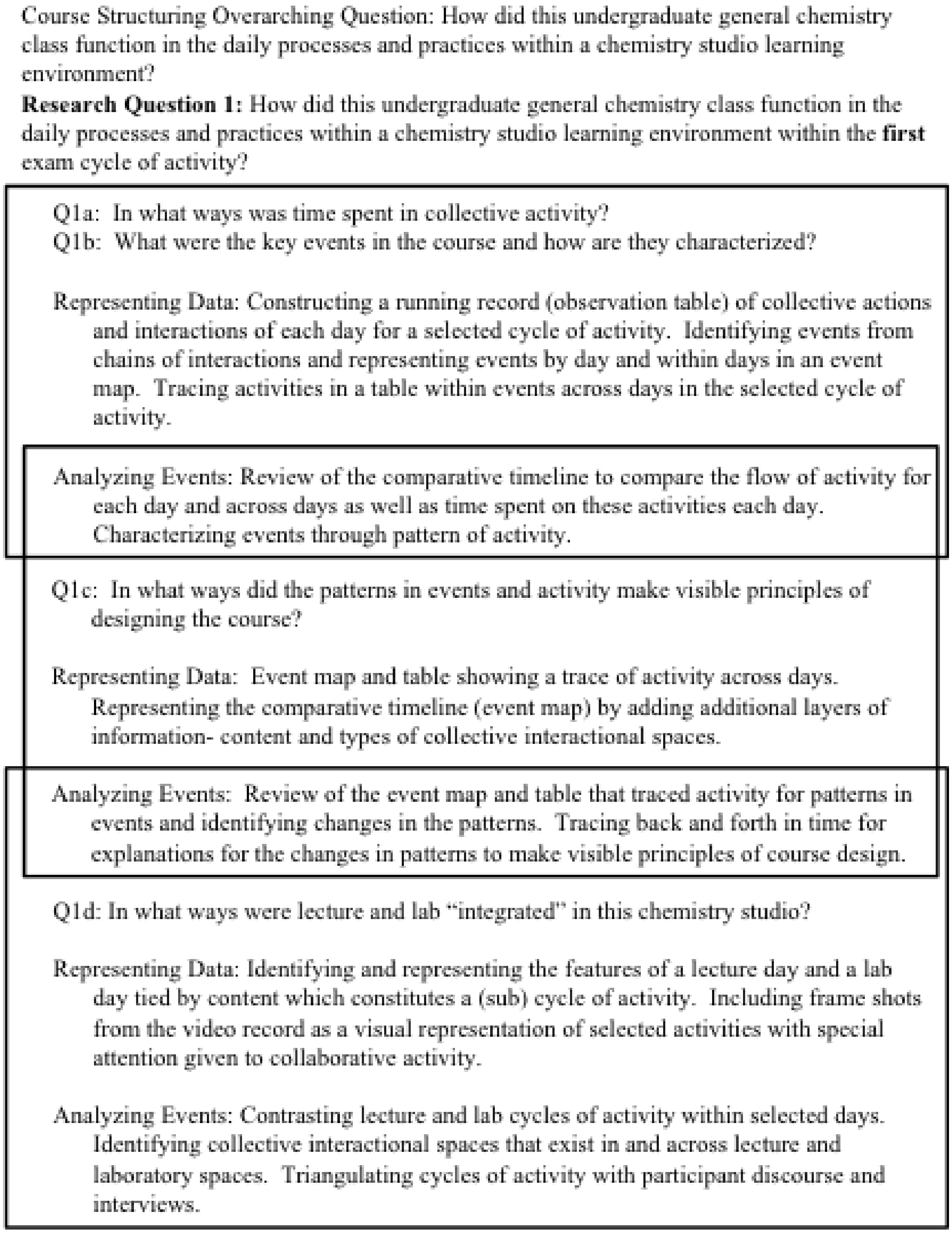
Collected artifacts. The notes that the instructor produced during the lecture events as well as any handouts provided to the students were collected. The online course website and laboratory guide were also available as part of the study. Finally, two course textbooks were accepted as course texts and made available for study (Silberberg, 2009; Tro, 2011). However, the instructor advised students on the first day of class that any general chemistry textbook could be used as a reference in this class.

Data Analysis Methodology

The process. Within an ethnographic perspective, data analysis uses an abductive logic that consists of iterative and recursive processes (Agar, 2006; Green et al., 2012). The process is abductive (Agar, 2006) in that the phenomena is examined through a series of research questions where the analysis of one research question provides the basis of the next research question. Recalling the difference between "records" and "data" as discussed previously in this section, the process is iterative in that research questions must be considered within the capacity of the records to, first, be represented as data which can, second, address the question. The researcher iteratively goes from question to records to data and back to question while at the same time considering insights that may inform the process obtained from the iterative analysis of a prior research questions or the cumulative knowledge from data analysis up to that point. As such, each step of selecting records for representation as data and the way in which these data are represented is a deliberate act based in the capacity of the data to provide a basis for empirically warranting claims to support evolving research questions. The process is also recursive in that knowledge gained from new research questions can be used to inform analyses of prior questions. An iterative and recursive process reconciles records, data, and research question(s). In summary, the process is an abductive trace of questions through a data set analyzed with a series of iterative steps that can recursively reconsider each question and its data analysis with a newly informed perspective from accumulated knowledge about the cultural process(es) under study.

The logic of inquiry for this study is represented in Figures 8a and 8b for Phase I (Data Structuring) and Figure 8c for Phase II (Problem Solving). Each figure is shown as a series of interconnected blocks. Each block represents a stage of analysis. The abductive nature of this logic of inquiry is shown as each block of analysis is initiated by a question derived from the analyzing event that preceded it.

Although I was present for all records collection activities, I approached the process of data analysis as a re-entry into the available archive. Guided by my intent to explore and make visible “what is going on” within this general chemistry studio classroom, I used the video records of the class, video records of the interview with the instructor, and textual artifacts of the course as the basis of this study. As the primary source in constructing data, the video records were repeatedly entered to



Course Structuring Overarching Question: How did this undergraduate general chemistry class function in the daily processes and practices within a chemistry studio learning environment?

Research Question 1: How did this undergraduate general chemistry class function in the daily processes and practices within a chemistry studio learning environment within the **first** exam cycle of activity?

Q1a: In what ways was time spent in collective activity?
Q1b: What were the key events in the course and how are they characterized?

Representing Data: Constructing a running record (observation table) of collective actions and interactions of each day for a selected cycle of activity. Identifying events from chains of interactions and representing events by day and within days in an event map. Tracing activities in a table within events across days in the selected cycle of activity.

Analyzing Events: Review of the comparative timeline to compare the flow of activity for each day and across days as well as time spent on these activities each day. Characterizing events through pattern of activity.

Q1c: In what ways did the patterns in events and activity make visible principles of designing the course?

Representing Data: Event map and table showing a trace of activity across days. Representing the comparative timeline (event map) by adding additional layers of information- content and types of collective interactional spaces.

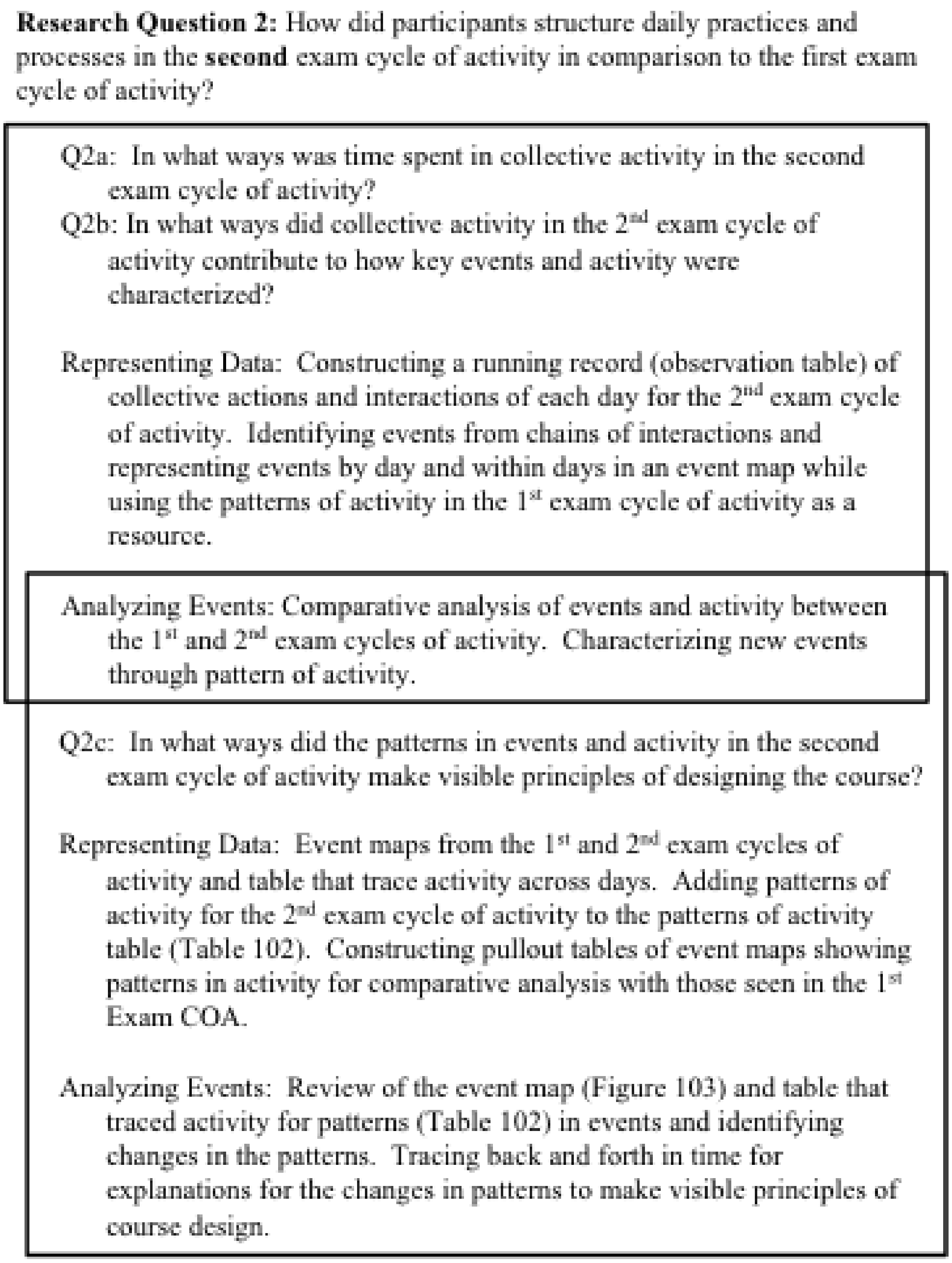
Analyzing Events: Review of the event map and table that traced activity for patterns in events and identifying changes in the patterns. Tracing back and forth in time for explanations for the changes in patterns to make visible principles of course design.

Q1d: In what ways were lecture and lab "integrated" in this chemistry studio?

Representing Data: Identifying and representing the features of a lecture day and a lab day tied by content which constitutes a (sub) cycle of activity. Including frame shots from the video record as a visual representation of selected activities with special attention given to collaborative activity.

Analyzing Events: Contrasting lecture and lab cycles of activity within selected days. Identifying collective interactional spaces that exist in and across lecture and laboratory spaces. Triangulating cycles of activity with participant discourse and interviews.

Figure 8a. Logic of inquiry for course structuring (Research Question 1) showing the analytical process.



Research Question 2: How did participants structure daily practices and processes in the **second** exam cycle of activity in comparison to the first exam cycle of activity?

Q2a: In what ways was time spent in collective activity in the second exam cycle of activity?

Q2b: In what ways did collective activity in the 2nd exam cycle of activity contribute to how key events and activity were characterized?

Representing Data: Constructing a running record (observation table) of collective actions and interactions of each day for the 2nd exam cycle of activity. Identifying events from chains of interactions and representing events by day and within days in an event map while using the patterns of activity in the 1st exam cycle of activity as a resource.

Analyzing Events: Comparative analysis of events and activity between the 1st and 2nd exam cycles of activity. Characterizing new events through pattern of activity.

Q2c: In what ways did the patterns in events and activity in the second exam cycle of activity make visible principles of designing the course?

Representing Data: Event maps from the 1st and 2nd exam cycles of activity and table that trace activity across days. Adding patterns of activity for the 2nd exam cycle of activity to the patterns of activity table (Table 102). Constructing pullout tables of event maps showing patterns in activity for comparative analysis with those seen in the 1st Exam COA.

Analyzing Events: Review of the event map (Figure 103) and table that traced activity for patterns (Table 102) in events and identifying changes in the patterns. Tracing back and forth in time for explanations for the changes in patterns to make visible principles of course design.

Figure 8b. Logic of inquiry for course structuring (Research Question 2) showing the analytical process.

Problem Solving Overarching Question. Within this studio learning environment, how are problem solving practices proposed and taken up by students?

Initiating Question: How did participants construct opportunities for learning how to use or apply concepts in this course?

Research Question 3. In what ways did the instructor frame (or position) problem solving in course documents and introductory comments in the course?

Representing Data: Representing select course documentation in a table by sentence (structuring element in written text). Representing select instructor discourse in transcripts. Taxonomic charts showing relationships implicated from course documentation (written) and instructor guidance (verbal).

Analyzing Events: Content and rhetorical analysis of course documentation showing how the instructor positions problem solving and influences students to do problems solving. Taxonomic analysis mapping features of how the instructor positions problem solving.

Research Question 4. In what ways was select disciplinary content proposed and negotiated by instructor and students in collective activity?

Representing Data: Trace of events that contribute to the constructing of what is required to know and use/apply select disciplinary content from observation tables, event maps, instructor notes, and video records.

Analyzing Events: Tracing the process of participants constructing what is required to know and do with respect to select content.

Research Question 5. In what ways did students construct opportunities for learning how to use or apply concepts for the select disciplinary content (in Question 4) within lab-partnered group and table interactional spaces?

Representing Data: Map of student positions for the table group under study showing salient demographic information. Constructing an event map by student lab-partnered group from observations tables (by group). Transcripts of student discourse for two disparately performing lab-partnered groups in the same table group as they negotiate the lab requirements during a laboratory experiment for the select disciplinary content.

Analyzing Events: Selection of two of four lab-partnered groups for detailed analysis. Comparative analysis of discourse practices of the two select student lab-partnered groups in how and ways that they construct opportunities for learning how to use or apply the select disciplinary as they negotiated the lab experiment.

Figure 8c. Logic of inquiry for problems solving (Research Questions 3, 4, and 5) showing the analytical process.

construct data for analysis throughout the data analysis process. From the archive, I used the video from the primary camera and only viewed records from the secondary camera when needed. Recalling that methodology implicates the theoretical issues that guide how methods are used in practice, the study methodology showing relationships between research questions, records and data, data analysis and guiding literature is shown in Table 1.

Descriptives of the analysis system. At this point it will be helpful to share some key definitions and relationships used in data construction and analysis.

Cycle of activity. A cycle of activity "...indicates a complete series of actions about a single topic or for a specific purpose" (Green & Meyer, 1991, p. 150). Cycles of activity at the largest scale cover the largest content areas such as thermodynamics or quantum theory or, in this case, content covered in a testing cycle. Smaller scale cycles of activity can also occur within other cycles of activity, say, over many days, one day or part of a day. According to Green and Meyer (1991), in order for events to be part of a cycle of activity, they "must be tied together by a common task or serve a common purpose" (p. 150). In this study, I consider several levels of cycles of activity ranging from a testing cycle covering nine days to a cycle of activity within one day made up of two events.

Table 1

Summary of Study Methodology

Questions	Records/Data Used	How Much?	Data Shown	Data Analysis/ Method	Conceptual/Methodological Element (Literature)*
1) How did this undergraduate general chemistry class function in the daily processes and practices within a chemistry studio classroom environment within the first exam cycle of activity?					
1a) In what ways was time spent in collective activity in this class? 1b) What were the key events in this course and how were they characterized?	Texts: Syllabus Field notes Video Records Obs Tables Event Map Table: Tracing Activity	35 hours for 9 class periods	1) Timeline of video/obs w/content 2) Event map of first exam cycle of activity 3) Table showing trace of activity within events	Video Analysis Discourse Analysis	Discursive Units of Analysis (Green & Wallat, 1981; Green, Skukauskaite, Dixon, & Cordova, 2007) Event Map (Kelly & Chen, 1999) Video Analysis (Baker, et al., 2008; Castanheira, Crawford, Dixon, & Green, 2001)
1c) In what ways did the key structuring features (patterns) in events and activity make visible principles of designing this course?	Texts: Syllabus Interviews (2) Transcripts Video Records Event Map from Q1 Table: Tracing Activity from Q1	2-one hour 20 hours	1) Event map of first exam cycle of activity 2) Select transcript segments	Video Analysis Discourse Analysis	Discursive Units of Analysis (Green & Wallat, 1981; Green et al., 2007) Constructing Transcripts (Gumperz & Berenz, 1993) Cycles of Activity (Green & Meyer, 1991)
1d) In what ways were lecture and lab “integrated” in this chemistry studio?	Interviews (2) Transcripts Video Records Event Map of 2-Day cycle of activity	2-one hour 5 hours	1) Event map of two day cycle of activity about enthalpy with pullouts of a lab cycle of activity and lecture cycle of activity 2) Select transcript segments 3) Still shots of group collaborative functions within table interactional spaces.	Video Analysis Discourse Analysis	Conducting Interviews (Spradley, 1979) Cycles of Activity (Green & Meyer, 1991) Video Analysis (Baker et al., 2008; Castanheira et al, 2001) Constructing Transcripts (Gumperz & Berenz, 1993)

Questions	Records/Data Used	How Much?	Data Shown	Data Analysis/ Method	Conceptual/Methodological Element (Literature)*
2) How did participants structure daily practices and processes in the second exam cycle of activity in comparison to the first exam cycle of activity?					
2a) In what ways did time spent in collective activity in this class in the 2nd exam cycle of activity? 2b) In what ways does collective activity in the 2nd exam cycle of activity contribute to how key events and activity were characterized?	Texts: Online Syllabus Field notes Video Records Obs Tables Event Maps of 1st and 2nd Exam COAs Table: Patterns of Activity	35 hours for 9 class periods	1) Timeline of key events by class day 2) Event map of 1st and 2nd Exam COAs 3) Table showing trace of activity within events	Video Analysis Discourse Analysis	Discursive Units of Analysis (Green & Wallat, 1981; Green et al., 2007) Cycles of Activity (Green & Meyer, 1991) Event Map (Kelly & Chen, 1999) Video Analysis (Baker et al., 2008; Castanheira et al, 2001; Green et al., 2007)
2c) In what ways did the patterns in events and activity in the 2nd exam cycle of activity make visible principles of designing this course?	Texts: Online Syllabus Interviews (3) Transcripts Video Records Obs Tables Event Maps from Q1 Table: Patterns of Activity from Q1	3-one hour 20 hours	1) Event map of second exam cycle of activity 2) Select transcript segments	Video Analysis Discourse Analysis	Discursive Units of Analysis (Green & Wallat, 1981; Green et al., 2007) Constructing Transcripts (Gumperz & Berenz, 1993) Cycles of Activity (Green & Meyer, 1991) Video Analysis (Baker et al., 2008; Castanheira et al., 2001; Green et al., 2007)
3) In what ways did the instructor frame (or position) problem solving in course documents and introductory comments in the course?	Texts- Online Syllabus Achieving Success (AS) in Chem 124 Course Guidelines Video Records Select Transcripts	70 hours for 18 class periods	1) Table for Content and Rhetorical Analysis 2) Taxonomic Map for Problem Solving IAW AS in Chem 124 3) Taxonomic Map for Problem Solving including instructor verbal guidance in class 4) Select transcript	Content Analysis Rhetorical Analysis Discourse Analysis Taxonomic Analysis	Content Analysis (Huckin, 2004) Rhetorical Analysis (Selzer, 2004) Constructing transcripts (Gumperz & Berenz, 1993) Video Analysis (Baker, et. al., 2008; Castanheira et al, 2001; Green et al., 2007) Constructing a taxonomic map (Spradley, 1979) Co-constructing a “text” as resource (Bloome et al., 2010)

Questions	Records/Data Used	How Much?	Data Shown	Data Analysis/ Method	Conceptual/Methodological Element (Literature)*
4) In what ways was select disciplinary content proposed and negotiated by participants in collective activity?	Annotated Event Map from Q1b Observation Tables Instructor Notes Video Records Select Transcripts Pattern of Activity Table from Q1c	70 hours for 18 class periods	1) Figure showing trace of process within select activity or cycle of activity 2) Table showing trace of process across activities or cycles of activity	Video Analysis Discourse Analysis	Video Analysis (Baker et al., 2008; Castanheira, et al., 2001; Green et al., 2007) Constructing transcripts (Gumperz & Berenz, 1993; Mishler, 1991) Cycles of activity (Green & Meyer, 1991)
5. In what ways did students construct opportunities for learning how to use or apply concepts for the select disciplinary content within lab-partnered group and table interactional spaces?	a) Student Survey b) Student Demographics and Grades c) Classroom layout d) Video &Audio Records	1 hour video 4 hours audio	1) Taxonomic Map of student survey responses (a) 2) Demographics for Table Group (b, c) 3) Event Map for Groups 1 and 3 in Atomic Spectra Lab (d) 4) Observation tables for Groups 1 and 3 (d) 5) Transcripts of select discourse (d) 6) Event Map for Groups 1 and 3 with interactions overlay (d)	Video Analysis Discourse Analysis Taxonomic Analysis	Constructing a taxonomic map (Spradley, 1979) Video Analysis (Baker et al., 2008; Castanheira et al., 2001; Green et al., 2007) Constructing transcripts (Gumperz & Berenz, 1993; Mishler, 1991)

*Note: The methodology is based on an ethnographic perspective (Green, Dixon, & Zaharlick, 2003) and the situated nature (Heap, 1991) of cultural practices. This influences all phases of the study.

Hierarchical units to describe flow of communication. Whereas a cycle of activity can be used broadly at many levels of scale to identify actions and events that are related, there are other terms that have more definitive meanings. The message unit is the most basic of these. According to Grice (1971) (as cited in Gumperz & Cook-Gumperz, 2006), "…meaning must be defined in terms of the effect that a sender intends to produce by means of a message" (p. 68). Therefore, the message unit, the smallest utterance that carries a message, is an important construct and primary unit for analysis (Green & Wallat, 1981). In this hierarchical system, sequences of cohesively tied message units are action units. Turn-taking between actors constitute interactional units (Green et al., 2007). Sequences of thematically tied interactional units are called sequence units. Sequences of thematically tied sequence units then constitute a phase unit. Phase units, also called phases of activity here, further constitute subevents and events (Green & Wallat, 1981).

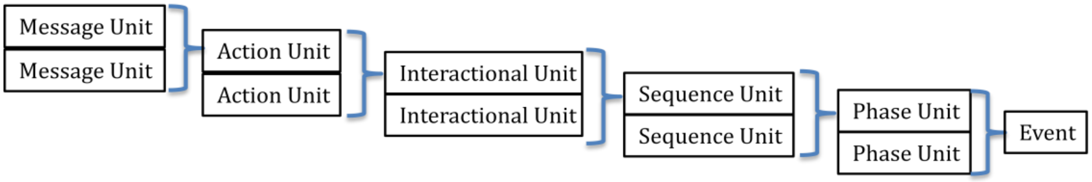


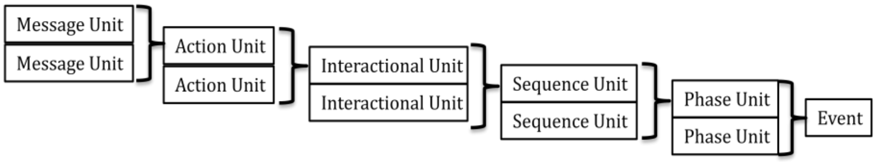
Figure 9. Diagram of relationship between hierarchical units describing communication as proposed by Green and Wallat (1981) and Green et al. (2007).

For purposes of this study, all events were first constructed by identifying phases of activity from a related series of actions from the observation tables from each day in the cycle of activity selected for analysis. Phases of activity are the major steps that make up a workbook problem event. For example, in a workbook problem event, phases of activity include, first, the instructor introducing a workbook problem and, second, students doing the workbook problem in groups. Other data were constructed by beginning with events identified from the observation tables and deconstructing these by phase of activity and then sequence units as determined by viewing the video records again and consulting the observation tables. Even with data products, in all cases, the video record was consulted to provide the context for description and interpretation.

Forms of data. In this study, I constructed four main forms of data as the basis for most of the analysis: observation tables, event maps, transcripts, and taxonomic maps. A summary of how the forms of data were constructed using the system of hierarchical units is shown in Table 2.

Table 2

Summary of How the Forms of Data Were Constructed from Hierarchical Units



Data Form	Relationships Between Hierarchical Units and Use as Data					
	Message Unit	Action Unit	Interactional Unit	Sequence Unit	Phase Unit	Event
Observation Tables	Unit of Analysis (not shown)	Derived from Message Unit			Derived from Action Units	Derived from Phase unit
Event Maps						Unit of Analysis (from Obs Tables)
Transcripts	Unit of Analysis					

Observation tables. Observation tables list participant actions observed from the video records from the perspective of the video vantage point. These served as the base documentation showing one perspective of actions occurring in the video records. Time stamps were anchored in the official class start time as noted in the field notes. Derived from viewing and interpreting contextually tied message units as an action, actions were recorded for participants, specifically, the professor and the students from the "instructor" video record. The wider angle "group" video was used as a secondary source to determine collective actions to construct the observation tables. Student actions were identified as collective action(s) or by individual action(s) within or representing the collective. This running list of participant action served as the basis for constructing the hierarchy of units used in this study (Green & Wallat, 1981). An example of an observation table (see Appendix B) shows actions of participants which were grouped into phases of activity and then events.

Event maps. Event maps are summarized extensions of the observation tables. Derived directly from the observation tables, sets of phases of activity linked in time and functioning collectively were assigned a cover term which named the event (or subevent). The boundaries of these collective actions that constituted an “event” were determined by a significant shift in action such that actions occurring before the boundary contrast with the actions that occurred after the boundary (Green & Meyer, 1991). In assigning cover terms to these bounded events, I used the names of events given by the actors as folk terms (Spradley, 1979). Assigning labels in this way ensures that understandings of actions and events remain as close as possible to the emic perspective. What the event map makes visible is accessible in two ways, first as an extension of the observation tables within that same document (see Appendix B1) and then in a more refined form in a separate document showing the events scaled to time for the select days. This event map shows patterns in events for comparison across days. In this way, events and subevents could be contrasted in time (length of one event) and over time (to contrast similar events). Different representations of event maps are used in this study. Each is constructed in a specific and different way for a specific purpose.

Transcripts. Discourse within video records was represented as a transcript once these portions of the records were required for analysis. The theoretical basis for transcript construction involved seeing transcripts as a record of an interpretation as explained by Gumperz and Berenz (1993):

> Transcription is an integral part of an overall process of interpretive analysis that includes both the translation of oral readings into written symbols and the evaluation or assessment of communicative intent. (p. 92)

In order to represent discourse, transcripts show one message unit per line or are separated by "\" or "/" and are void of capitalization and punctuation as indicators of sentence structure. Rather, message units are discerned by contextualization cues which include intonation, pauses, gestures, and changes in orientation (Gumperz & Berenz, 1993). To help discern communicative intent, segments of transcript that included referenced line numbers are provided for context in transcripts shown.

Ways to visually represent transcripts for separating speakers and speaker overlap was also influenced by Mishler (1991).

Taxonomic Maps. A taxonomic map (Spradley, 1980) is a representation of the elements and relationships between actors, actions, ideas, cultural artifacts, roles, and others as signaled by interactions within a cultural group. Grounded in cultural anthropology, taxonomic maps represent these cultural systems from an emic perspective. In this study, students survey responses are categorized using a taxonomic map. Taxonomic maps also represent a synthesis of information from more than one analysis. Here, taxonomic maps are also constructed from analysis of relationships inferred from content and rhetorical analysis of course documentation and discourse analysis of transcripts from instructor interactions with students.

Methods of analysis. Many of methods of analysis used in this study have been explicitly and implicitly explained through how data forms were constructed. In Table 3, I summarize each of the analyses based on how these were used in this study. All analyses were conducted in accordance with the presented conceptual framework based on the key literature shown in Table 3. More detailed discussions of data analysis are also found in the next two chapters.

Table 3

Methods of Analysis

Type	Definition	Use in Study	Key Literature
Video Analysis	Interpreting video (and corresponding audio) records for representation in a data form for potentially further analysis	Used as primary means and source for data construction of transcripts, observation tables and event maps	Baker et al. (2008) Castanheira et al. (2001) Green et al. (2007)
Discourse Analysis	Includes representing discourse from video (or audio) records and inferring meaning from how participants position and are positioned by each other	Provides logic for construction of transcripts from video/audio records. Primary analysis for inferring meaning of interactions and actions.	Bloome et al. (2010) Gumperz & Berenz (1993) Mishler (1991)
Content Analysis	"...the identifying, quantifying, and analyzing of specific words, phrases, concepts, or other observable semantic data in a text or body of texts with the aim of uncovering some underlying thematic or rhetorical pattern running through these texts." (Huckin, 2004, p. 14)	Focuses on the meaning of the text under analysis.	Huckin (2004)
Rhetorical Analysis	"...can be understood as an effort to understand how people within specific social situations attempt to influence others through language." (Selzer, 2004, p. 281)	Focuses on the rhetorical elements that show *how* the text means.	Selzer (2004)
Taxonomic Analysis	A process of inferring relationships between actors, actions, ideas, cultural artifacts, roles, and others as signaled by interactions or actions within a cultural group.	Means of visually representing relationships for problem solving and applying concepts	Spradley (1979)

Chapter IV: Data Analysis and Findings - Course Structuring

Overview

At the onset of data analysis for this study which focused on problem solving practices in this course (and is discussed in Chapter V), it was clear that I would not be able to effectively address phenomena occurring within this chemistry studio learning environment without clearly articulating how this general chemistry studio course functions. As such, I first provide this detailed analytical description to demystify the designing of instruction in what has been called an "integrated lab and lecture" by cultural insiders (Neff, Course Documentation, Winter 2012). Namely, this chapter addresses how and in what ways participants structured daily practices and processes in this general chemistry studio. Although the primary intent of this detailed analysis is to characterize the co-constructed events and activity as a resource for Chapter V, this chapter also serves as a stand-alone guide for instructors new to a chemistry studio learning environment for ways of thinking about what is happening in their classrooms.

Because of the sheer volume of material to analyze, the unit of analysis was selected that strategically divided the archive into two parts by content and time (see Figure 10). As such, the first research question addresses the first three weeks (Weeks 1-3) of the course consisting of disciplinary content included in the first exam. This analysis focuses on the foundational structuring elements (events and activity) that characterized how this course functions in daily classroom life. The second research question continues this same type of analysis for Weeks 4-6 but focuses on how the nature of this disciplinary content influenced and modified the patterned events and activity of the course.

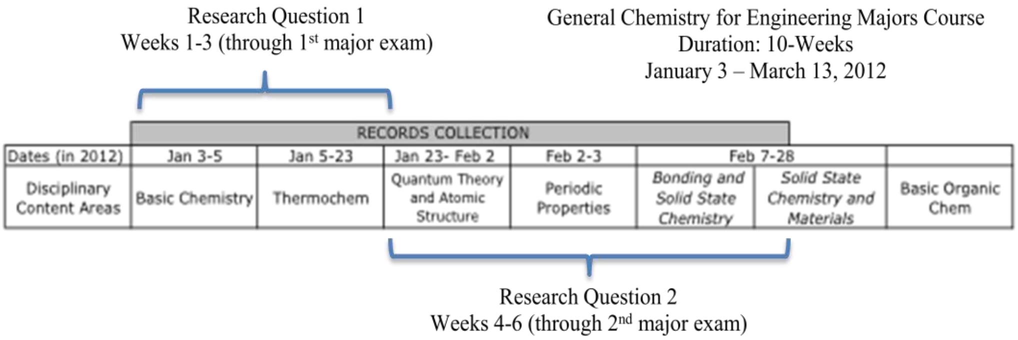


Figure 10. Overview of the content and time covered in Chapter IV by research question.

Research Questions

The research questions addressed in this chapter are:

Research Question 1. How did this undergraduate general chemistry class function in the daily processes and practices within a chemistry studio learning environment within the first exam cycle of activity?

Question 1a. In what ways was time spent in collective activity?

Question 1b. What were the key events in this course and how were they characterized?

Question 1c. In what ways did patterns in events and activity make visible principles of designing the course?

Question 1d. In what ways were lecture and lab "integrated" in this chemistry studio?

Research Question 2. How did participants structure daily practices and processes in the second exam cycle of activity in comparison to the first exam cycle of activity?

Question 2a. In what ways was time spent in collective activity in the second exam cycle of activity?

Question 2b. In what ways did collective activity in the second exam cycle of activity contribute to how key events and activity were characterized?

Question 2c. In what ways did the patterns in events and activity in the second exam cycle of activity make visible principles of designing the course?

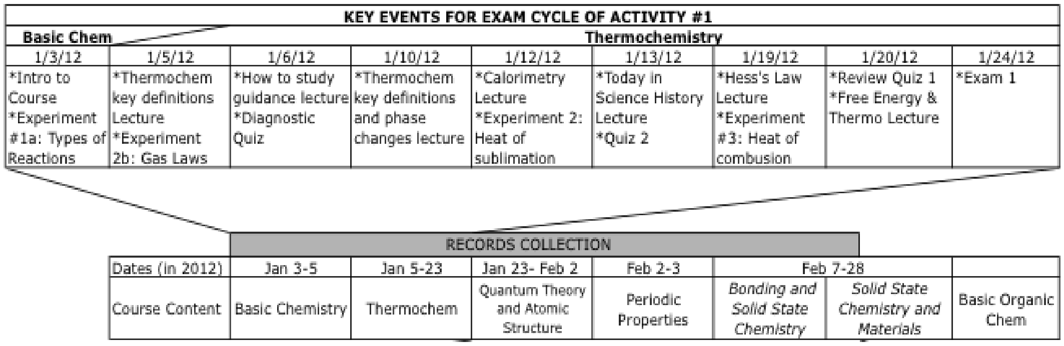
Data and Findings by Research Question

Research Question 1. How did this undergraduate general chemistry class function in the daily processes and practices within a chemistry studio learning environment within the first exam cycle of activity?

This first research question, comprised of four sub-questions, addresses how the participants structure their daily activity in the course based on the co-constructed events and activity in the first three weeks of the course. This analysis is presented as a progressive disclosure at descending levels of scale beginning with how time is spent and ending with detailed representations of key activities within a class period. This detailed examination of day-to-day and, at times, moment-to-moment events and activities makes visible how participants co-constructed the designing elements of the course as well how the conceptual framework guides the construction and analysis of data from archived records.

Research Question 1a. In what ways was time spent in collective activity?

Figure 11 shows how time was spent with respect to disciplinary content for the 10-week course and key events for the first exam cycles of activity (Green & Wallat, 1981). The first exam cycle of activity covered the basics of chemistry and thermodynamics content. The thermodynamics content was the first major new content area after reviewing basic chemistry concepts (reaction types and gas laws) which students were expected to have learned in high school. As the first cycle of activity of new content, exploring activities during this time also made visible the processes of constructing disciplinary content within the collective interactional spaces of the class. The second exam cycle of activity (weeks 4-6) consisted of quantum theory and atomic structure, periodic properties, bonding, and the first portion of solid state structure content.



KEY EVENTS FOR EXAM CYCLE OF ACTIVITY #1								
Basic Chem	**Thermochemistry**							
1/3/12	1/5/12	1/6/12	1/10/12	1/12/12	1/13/12	1/19/12	1/20/12	1/24/12
*Intro to Course *Experiment #1a: Types of Reactions	*Thermochem key definitions Lecture *Experiment 2b: Gas Laws	*How to study guidance lecture *Diagnostic Quiz	*Thermochem key definitions and phase changes lecture	*Calorimetry Lecture *Experiment 2: Heat of sublimation	*Today in Science History Lecture *Quiz 2	*Hess's Law Lecture *Experiment #3: Heat of combusion	*Review Quiz 1 *Free Energy & Thermo Lecture	*Exam 1

	RECORDS COLLECTION						
Dates (in 2012)	Jan 3-5	Jan 5-23	Jan 23- Feb 2	Feb 2-3	Feb 7-28		
Course Content	Basic Chemistry	Thermochem	Quantum Theory and Atomic Structure	Periodic Properties	*Bonding and Solid State Chemistry*	*Solid State Chemistry and Materials*	Basic Organic Chem

Figure 11. Pullout of key events in the first exam cycle of activity (9 class periods).

In order to show the part-to-whole relationships that constitute collective activity in this course, layers of analysis are shown as a progressive disclosure for the first major exam cycle of activity as a “telling case” (Mitchell, 1984) showing how this course functions. The first exam cycle of activity was selected for this detailed analysis because this is the time and space (at the collective level) where participants negotiate requirements for membership in this cultural group. In practical terms, this is a negotiation of roles, relationships, rules and obligations through how and in what ways that participants position each other and hold each other accountable. Therefore, this is an ideal space to examine who can do what, with whom, for what purpose, and with what outcome within the structuring events and activities of the course which are initiated in this first exam cycle of activity.

Figure 12 is an event map of the first exam cycle of activity. This provides a more detailed perspective of the events within collective interactional spaces showing how time is spent for the first exam cycle of activity identified in Figure 11. Figure 12 was constructed by identifying bounded events from major shifts in activity of the collective from observation tables of Days 1-9 (see Appendix B for example of observation table for Day 4) as discussed in the Methodology section. In Figure 12, time at ‘0’ is defined for each day as the start of an event within a collective interactional space such as Professor N greeting the class. In these first nine days, collective events were initiated by the instructor greeting the class or by giving a directive to the class to turn in an assignment. In this figure, color identifies events with similar disciplinary content such as thermodynamics shown in blue. Patterns in

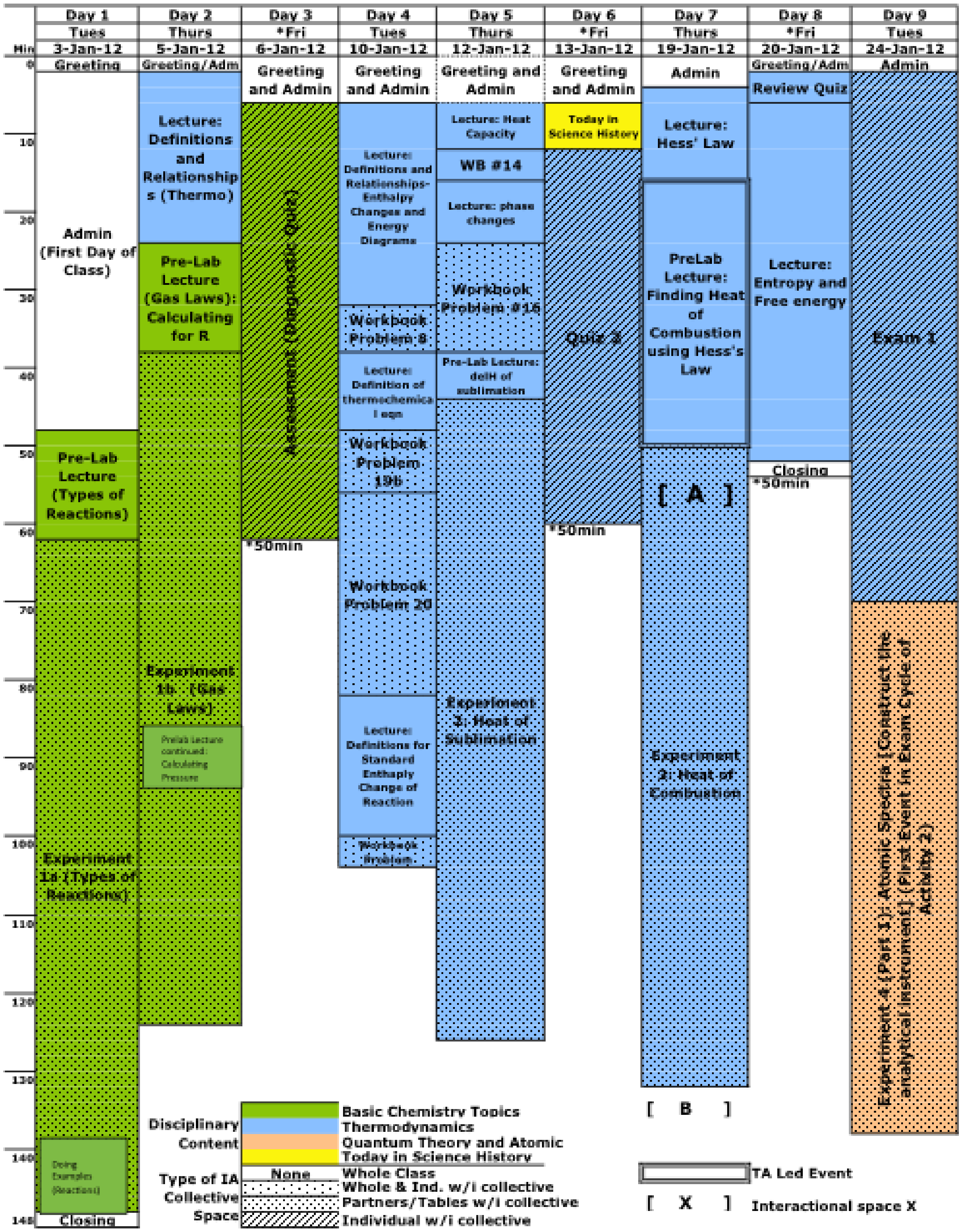


Figure 12. Event map showing how time is spent in collective activity in the 1st exam cycle of activity by disciplinary content and interactional (IA) collective space.

the events discern the different types of collective interactional spaces accessed in each event. To represent how time is spent, I only studied actions in collective interactional spaces which consisted of class meetings. To discern the different types of collective actions, these were categorized deductively from the observation tables as follows: 1) whole class, 2) whole class and participation as lab partners and/or tables within the collective, 3) lab partners and table within the collective, and 4) individual actions within the collective.

Another surface feature of Figure 12 in the difference in total time spent in collective spaces across days. This difference is due to the differences in the official length of time of the class through the week. The class is scheduled to meet on Tuesdays and Thursdays for 2 hours and 20 minutes and on Fridays for one hour. Because of the schedule, Professor N generally planned for Tuesdays and Thursdays to be a "lecture day" or a "lab day" as shown in Days 1, 2, 5, and 7. Assessments were planned for Fridays (Days 3 and 6). In this cycle of activity, we see this pattern holding until Day 8. What is not shown in this diagram is that the planning pattern was interrupted by a holiday that caused the class to not meet on Tuesday, January 17th. As a result, the instructor decided to delay the exam until the following Tuesday (Day 9) and conduct a lecture activity on free energy and entropy on Friday (Day 8).

Research Question 1b. What were the key events in this course and how were they characterized?

Within a conceptual framework where practices and processes in a classroom are co-constructed (Vygotsky, 1978; Heras, 1994; Kelly & Chen, 1999) key events in this course must be determined by tracing the patterns of (and changes in) actions of participants over time.   Table 4 shows the types of key events of the course and their characterizing activities for the cycle of activity under study. Collective activities that characterize each event are annotated with an ‘x’ for each day that the activity occurred as determined from the observation tables (Days 1-9). As members of this cultural group co-construct similar patterns of actions and interactions within an event, these experiences serve as a common resource that build common understandings (Edwards & Mercer, 1987) of roles and relationships, responsibilities and obligations, and expectations for future events of the same type.

In accordance with Table 4, the recurring types of key events that propose disciplinary content or practices to students in the cycle of activity under study are the following: greeting and administration, lecture, workbook problems, pre-lab lecture, and experiments. The table shows that events are characterized by patterns of activity; events do not occur in the same way (with the same activities occurring) every time. Rather, there is some variability with regards to what activities constitute an event as it occurs.

In this section, I have shown how participants used time with respect to content, collective interactional spaces, and activities. The event map (Figure 12) and the patterns of activity that characterize these events (Table 4) are the foundational data sources upon which the remainder of the data analysis will be constructed.

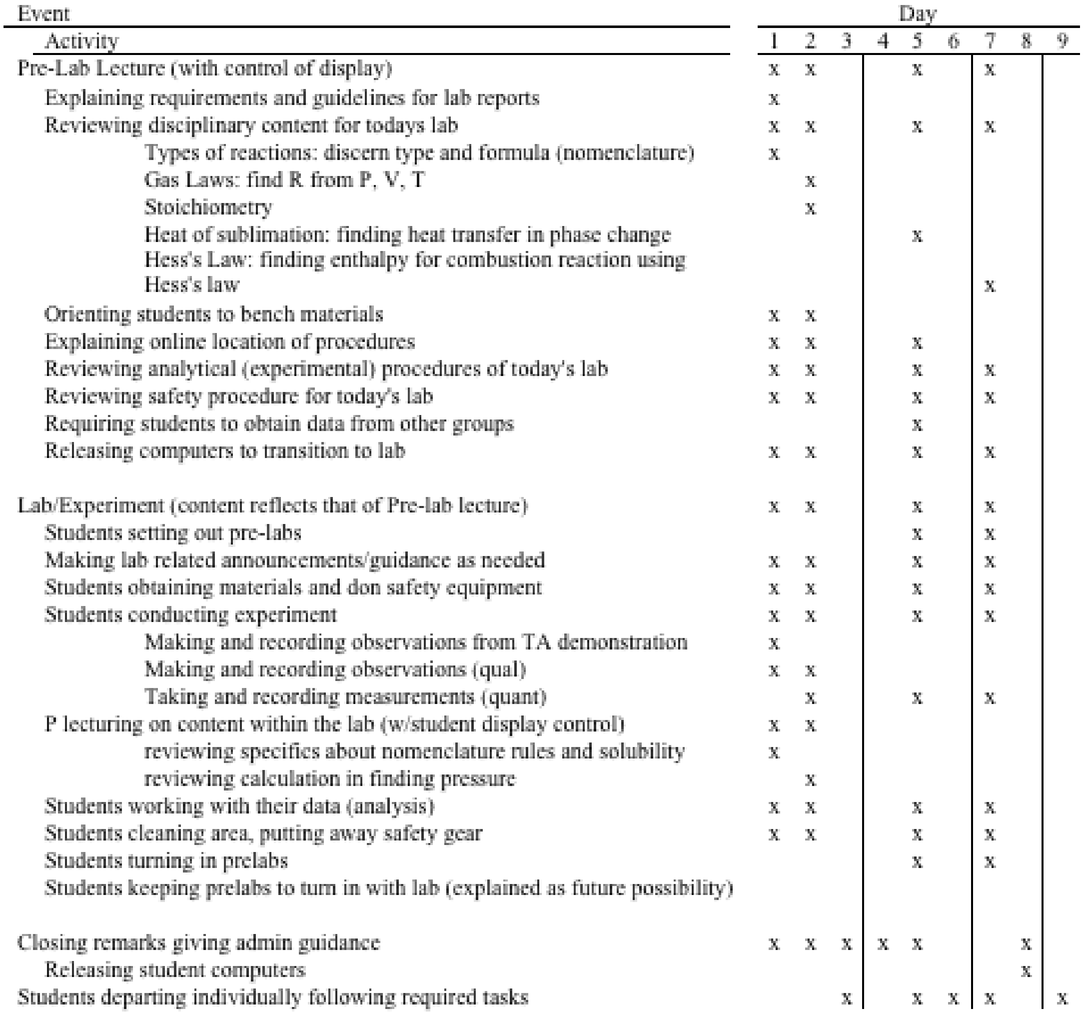
Table 4.

Patterns of Activity that Characterize Key Events in the First Exam Cycle of Activity

Event	Day								
Activity	1	2	3	4	5	6	7	8	9
Using speaker system when addressing whole class	x	x	x	x	x	x	x	x	x
Greeting and Admin	x	x	x	x	x	x	x	x	x
P taking control of student computers to display information	x	x	x	x	x	x	x	x	x
Announcing brief administrative details about schedule/plan	x	x	x	x	NA	x	x	x	x
Providing guidance for key aspects of the course (w/control of display)	x								
Explaining how lecture occurs	x								
Orienting to computer resources	x								
Explaining how to do workbook problems in class	x								
Providing guidance for doing problems outside of class	x			x					
Explaining what students should know already (from HS)	x								
Explaining safety guidelines for lab (general for all labs)	x								
Providing guidance for studying, negotiating problems, taking notes	x		x						
Providing guidance for pre-lab, lab report/conclusion				x					
Providing guidance about preparing for exam							x		
Reviewing past assessment: quiz								x	
Lecture: Today in Science History						x			
Quiz or Exam			x			x			x
Orienting to quiz/exam materials and admin for quiz/exam			x			x			x
Quiz or Exam: Students taking an individual assessment			x			x			x
Lecture (With control of display)		x		x	x		x	x	
Review of past content as transition to new content				x	NA		x	x	
Providing disciplinary content- definitions and equations	x	x		x	x		x	x	
Solubility rules	x	x							
Nomenclature	x	x							
Thermochem- forms of energy and heat definitions		x		x					
Internal energy, energy diagrams, combustion reaction				x					
Thermochemical equations				x					
Enthalpy/Standard heat of reaction				x					
Heat capacity, phase changes, heating curve					x				
Hess's law							x		
Entropy and Free energy								x	
Providing disciplinary content- applying concepts in examples	x	x		x	x		x	x	
Explaining content with demonstration (hand warmers)				x					
Using a handout to help students engage with qualitative content							x	x	
P leading students through problem(s)							x	x	
Providing metadiscourse on finding solution							x	x	
Obtaining student feedback in getting to solution							x	x	
Workbook Problems (Content reflects lecture content)				x	x				
Providing problem number and context				x	x				
Involving doing a calculation				x	x				
Students working individually or in groups on problem(s)				x	x				
P leading students through problem(s)					x				
Releasing computer control to students as they work the problem				☐					
Providing metadiscourse on finding solution				x	x				
Obtaining student feedback in getting to solution				x	x				

Table 4 (continued).

Patterns of Activity that Characterize Key Events in the First Exam Cycle of Activity



Event	Day								
Activity	1	2	3	4	5	6	7	8	9
Pre-Lab Lecture (with control of display)	x	x			x		x		
Explaining requirements and guidelines for lab reports	x								
Reviewing disciplinary content for todays lab	x	x			x		x		
Types of reactions: discern type and formula (nomenclature)	x								
Gas Laws: find R from P, V, T		x							
Stoichiometry		x							
Heat of sublimation: finding heat transfer in phase change					x				
Hess's Law: finding enthalpy for combustion reaction using Hess's law							x		
Orienting students to bench materials	x	x							
Explaining online location of procedures	x	x			x				
Reviewing analytical (experimental) procedures of today's lab	x	x			x		x		
Reviewing safety procedure for today's lab	x	x			x		x		
Requiring students to obtain data from other groups					x				
Releasing computers to transition to lab	x	x			x		x		
Lab/Experiment (content reflects that of Pre-lab lecture)	x	x			x		x		
Students setting out pre-labs					x		x		
Making lab related announcements/guidance as needed	x	x			x		x		
Students obtaining materials and don safety equipment	x	x			x		x		
Students conducting experiment	x	x			x		x		
Making and recording observations from TA demonstration	x								
Making and recording observations (qual)	x	x							
Taking and recording measurements (quant)		x			x		x		
P lecturing on content within the lab (w/student display control)	x	x							
reviewing specifics about nomenclature rules and solubility	x								
reviewing calculation in finding pressure		x							
Students working with their data (analysis)	x	x			x		x		
Students cleaning area, putting away safety gear	x	x			x		x		
Students turning in prelabs					x		x		
Students keeping prelabs to turn in with lab (explained as future possibility)									
Closing remarks giving admin guidance	x	x	x	x	x			x	
Releasing student computers								x	
Students departing individually following required tasks			x		x	x	x		x

x = identified in the records
NA = not available in records
☐ = discussed by P as an option in the records
P = Professor N

These representations will be referenced and deconstructed in multiple ways in order to make visible the practices and processes of this class.

Research Question 1c. In what ways did the patterns in events and activity make visible principles of designing the course?

Within a contrastive perspective (Green et al., 2003; Heap, 1991), similarities and differences in patterns of events and patterns of activity within events often make visible cultural practices and processes of (and are often invisible to) a cultural group (Green & Meyer, 1991). In this section, I compare patterns of activity within events as the unit of analysis using Table 4 and Figure 12 to identify key practices and processes that the instructor cultivated in the designing of opportunities for learning within the key events in this chemistry studio.

Designing for the pre-lab lecture event. By using patterns of activity to identify cultural practices in working across time and events in Figure 12, in this section I show the process of understanding how the instructor designed opportunities for learning in how she planned for a pre-lab lecture. An interesting feature made visible in the mapping of events over time (within days and across days) shows that in the first two experiments (Days 1 and 2 of Figure 12) an 8-10 minute lecture event occurs about two-thirds into the time of the ongoing lab. However, by comparative analysis, this pattern does not occur in Experiments 3 and 4 (Days 5 and 7). In addition, by visual contrast of the length of the pre-lab lectures in Days 1, 2, 5, and 7, the pre-lab lecture conducted by the TA as instructor on Day 7 is twice as long as other pre-lab lectures taught by Professor N. These changes in patterns of activity (lecture activity within the lab) and the variability in duration of the pre-lab lectures are cause for further study to understand how the instructor designs opportunities for learning in the pre-lab event. Specifically, these opportunities are with regards to the differences in ways of developing declarative knowledge or practices.

With review of observation tables and the video records for Day 7, Interactional Space A, a discussion between the TA and professor as annotated in Figure 12, makes visible how the instructor designs for the pre-lab lecture. The content of the discussion (see Table 5) shows that Professor N has adjusted plans for design of the pre-lab lecture as a response to student "inattention".

In dialogue in Table 5, the instructor explained to the TA that she does not plan to give all the calculations to the students in the pre-lab lecture (before they begin the lab) because of lack of student attention (Line 53) signaled by an increase in student talking and non-verbal cues (Lines 63-65). Rather, she intentionally delayed the calculations portion of the pre-lab lecture until a point in the lab when students have obtained some data (Line 55) and students would be more attentive.

Following the class on Day 7 (see Interactional Space B in Figure 12), the professor provided unsolicited feedback to me (see Table 6) about the TA’s pre-lab lecture which gave Professor N an opportunity to reflect on how she came to plan for the lecture within the lab event as a designing principle for this event in this class.

These excerpts from Day 7 show that Professor N purposefully planned for designing a pre-lab lecture in parts (Figure 12, Days 1 and 2) in order to propose specific content at times when the students would recognize the need for the information (Table 6, Lines 49-54). This gave context to the instructor dialogue in the pre-lab lecture on Day 2 (not shown here) when she announced to students prior

Table 5

Transcript of Selection of Professor (left) and TA (right) Dialogue (Interactional Space A of Day 7 in Figure 12) (Lines 38-66)

Line	Professor N	TA
38	and I learned this the hard way	
	you can	
40	in this class	
	you can totally tell	
	when they’ve stopped paying attention	
		yeah
		I know
45	and I know that you got it	
	you heard it	
		yeah
	um	
	and that’s why I used to do all this stuff	
50	like the calculations and everything	
	at the beginning (before the lab)	
	but because they start	
	they stop paying attention	
	I’ve ended up moving it to after	
55	and do it after they’ve collected some data	
	and I don’t	
	I still sometimes wonder	
	how many of them are listening to me	
	but	
60		yeah
		I know
	I think more of them are (listening)	you can totally tell (students not listening)
	because they start moving more	
	and there is just a little more (student) talking	
65	and this background hum	
		yep

to starting the experiment that the pressure calculation, the more challenging conceptual content of the experiment, would be presented after the students had obtained some pressure data. The instructor then initiated the lecture activity within the lab to propose information for the pressure calculation after several students had asked how to do the pressure calculation. By raising questions about the pressure calculation, students signaled to the instructor that this was an optimal time in the

Table 6

Transcript of Selection of Professor (left) Dialogue with the Researcher (right) in Interactional Space B on Day 7 (Lines 35-59)

Line	Professor N	TA
35	so I think I learned the hard way	
	oh	
	I can’t do that before the experiment	
	I have to wait until after	
	when they’ve done it all	
40	and they’ve collected all the data	
	and they are paying attention again	
	for a while I had a really hard time calling them back	
	together	
	but I’ve just gotten	
45	to the point where I just force it	
	you say	
	you know	
	ok	
	now everybody	
50	I know you want to get outta here	
	but we’re going to talk about the calculations	
	and trust me	
	this is going to help you	
	and they do pay attention	
55	but he (the TA) had already been talking	once you see the need is there
	yeah	
	he had already been talking for 20 minutes	
	half an hour	
	and they were already starting to lose	
	(Interrupted by student asking a question)	
	(Time: 2:11:28)	

students’ collective progress through the lab to present ways of thinking about the pressure calculation.

Analysis of the pre-lab lecture activities in Table 4 shows that the elements common to all pre-lab lectures are that the instructor proposes disciplinary content and directs safety guidelines and analytical procedures for the lab. These indicate that

Professor N's *role* in this event is to contextualize the lab with respect to disciplinary content and direct actions expected of students during the lab.

Designing for "lecturing" as an activity. At this point it is helpful to distinguish between the lecture as an event (as shown in Figures 12 and Table 4) and lecture as an activity which is more clearly called "lecturing". *Lecture* is the name of an event where the instructor proposes disciplinary content in a specific way (by *lecturing*). There are two types of lecture events as shown in Figure 12 and Table 4 and discussed previously: the "lecture" and the "pre-lab lecture". *Lecturing* is the means by which content is proposed in a lecture or a pre-lab lecture event. Participants often use the terms lecture and lecturing interchangeably. However, the distinction must be clear here because the types of *lecture* implicate disciplinary content while *lecturing* does not.

The word "lecturing" in this course means something very specific to this class that differs significantly from what "lecturing" looks like in a traditional lecture hall. Because of the physical design (size, dimensions, and seating design as shown in Figure 6), Professor N uses a remotely microphoned speaker system when addressing the class as a whole as annotated in the first activity line in Table 4. The means by which content is proposed to students in a lecture in this class is shown in Figure 13. When Professor N lectured, she wrote notes that were displayed to student computer screens via an overhead projector. At the same time, she explained disciplinary content via the speaker system so all students could see the notes and could hear her explanation without looking at her directly or at all. Upon examining the resources and layout of this classroom, it is difficult to see how an instructor could lecture in this chemistry studio in the traditional way – instructor writing and explaining notes on a chalkboard or whiteboard (see Figure 14). Although there were whiteboards available on one wall of the room, the classroom layout rendered these as

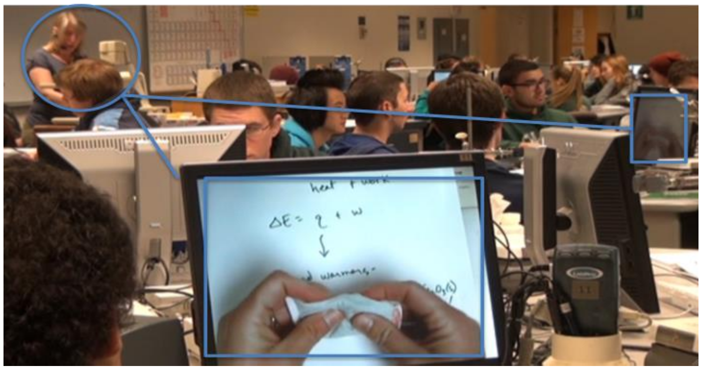


Figure 13. Frame grab showing what "lecturing" looks like in this studio classroom. Professor N demonstrated how a handwarmer works as an example of an exothermic reaction during lecture on Day 4. She explained content and wrote notes on the document camera (circled) displayed to student computer monitors (boxed).

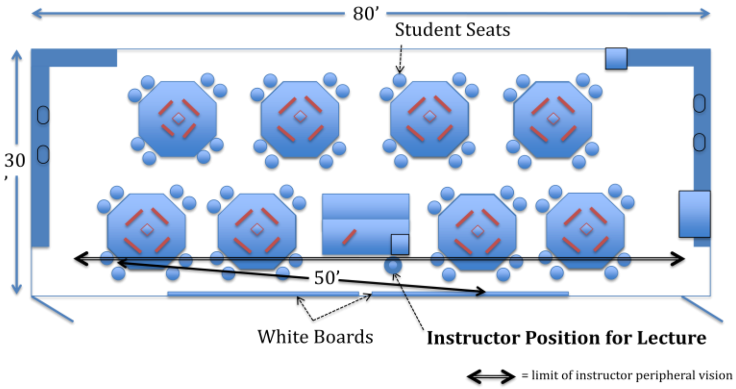


Figure 14. Limits to instructor and student views.

an ineffective means of displaying information to students. From a seat on the far left and the near side of the classroom, a student would have to see writing on the board from 50 feet away at an angle close to the plane of the board (see Figure 14). In addition, half of the student seats faced 180 degrees from certain portions of the boards. In this classroom design, most students could not see a significant portion of the boards without turning around. In fact, from some seating positions, students could not discern words on the boards at all.

Table 7

Transcript of Selection of Professor (left) and TA (right) Dialogue Regarding the TA Lecturing during a Pre-lab Lecture (See Figure 12, Day 7, Interactional Space A)

Line	Professor N	TA
	(Time: 53:45)	
	it’s weird for me to sit there and listen	
		yeah
		I bet
		is it good/
	yes	
5	the	
	the elmo (document camera) is really hard	
		I know
	to work with	
	your first time	
10		my first time
		yeah
		I was getting (inaudible)
		down the page
		even without realizing it
15	and it’s	
	I should have put it back on the y (axis)	
	cause I had it (document camera) zoomed in	
		that’s probably good it was in
		I write pretty small
20		just naturally
	it was actually zoomed in pretty far	

Even with displaying information to student computers, this means of lecturing has its own challenges. These challenges were made visible in the same "rich point" where the TA instructed the prelab lecture on Day 7. While the TA gave the pre-lab lecture, Professor N sat behind him in full view of the mechanics of his lecturing. In Table 7, Professor N explained to the TA how his challenges with lecturing made her think about the details of how she lectures.

In addition, a discussion after class on Day 7 as annotated in the non-collective Interactional Space B shown in Day 7 of Figure 12, the professor further explained this experience to me, the researcher.

Table 8

Transcript of Selection Dialogue of Professor N Commenting to the Researcher about Lecturing in the Chemistry Studio, Referencing How the TA Lectured on Day 7 (See Figure 12, Day 7 Interactional Space B)

Line	Professor N
	(Time: 2:09:45)
	this is such a hard class for students to teach
	for exactly the reasons that I noticed
	[inaudible] having a hard time with today
	and one of them is this thing (gesturing to document camera)
5	it's just awkward as hell
	if you've never done it before
	and I was watching him
	and I had it zoomed in pretty far
	so he was going off the page (on the computer display)
10	and then he wasn't watching (the instructor computer monitor)
	if he was going too
	if he was going [writing] too far down (on the document camera)
	and they [students] couldn't see (his writing)
	every once in a while he'd look (at the computer monitor)
15	and he'd go oh
	and he'd move it (the notes) up (on the document camera)

Both excerpts when cross referenced with field notes of how the instructor conducted a lecture make visible that the professor negotiated several variables while lecturing: magnification level of the document camera, placement of the paper on the document camera, placement of the writing on the paper to be displayed, monitoring of student progress by her observing their gestures and movements (non-verbal feedback), moving the paper up on the document camera so that students had time to write notes while she continued to write, what she said with respect to what she wrote, and the speed of what she wrote. From this example, we see that Professor N not only planned for what content to show to students, but in how this content was made present to students in the unfolding of the content in a way that students may consume the information efficiently. In addition, she was limited in how she could conduct these tasks within the technological capabilities of the studio classroom for lecturing. From this example, we see part of what was required for Professor N to conduct, not just a pre-lab lecture, but any lecture-based activity in this studio classroom.

Designing for a lecture event. According to Table 3, during all lecture events in this cycle of activity, Professor N proposed disciplinary content to students as definitions and equations, examples, or a demonstration as students asked questions for clarification and took notes. So, in the lecture event, Professor N's role was to tell students the disciplinary content that she believed they needed to know. The students' role was to take up the content by taking notes and asking questions. Just like in pre-lab lecture, the means of conducting a lecture event is by lecturing, and lecturing in this classroom impacts designing of the lecture event significantly. Figure 12 shows that Professor N conducted lecture events in 5-20 minute intervals and each lecture event covered enough information such that students could apply the information in a workbook problem thereafter. For example, within the major content area of thermodynamics covered on Days 2 to 9, the subtopic of enthalpy is covered on Days 4 to 6 and within several lecture events. One of these on Day 4 was how to account for enthalpy changes through a thermochemical equation. Professor N attributed her design decision to break up the lecture into smaller lectures to the students' lack of attention. The design of lecture events as it is integrated with other events within a class period will be discussed in detail in the next research question.

Designing for workbook problems as an event. According to Table 4, doing workbook problems was a distinct event with the following common elements: Professor N introduced and contextualized the problem; students were given time to work on the problem individually or in groups; once she saw that most students completed the problem, Professor N reoriented students as a class to the computer displays; and Professor N provided a narrative of her thinking as she did the problem while obtaining student feedback and/or answering questions as she produced her solution. Elements that varied in this event include that Professor N led students through all or a portion of the problem and that students may be given control of their computers to help solve the problem. In this case, the instructor verbally considered allowing students control of the computer to look up unit conversions. However, she decided that for this problem, she would display conversions for students herself.

The patterns of activity that characterized the workbook problem event are very similar to the patterns in activity involved in the lecture event when Professor N uses a handout or worksheet (See Table 4). Disregarding the first week of class where content was proposed strictly as a review, new content introduced in the lecture events on Days 4, 5, 7 and 8 is then applied in either a workbook problems (Days 4 and 5) or a handout (Days 7 and 8). However, the significance of the workbook problems are made visible on Day 1 when Professor N introduced the workbook as a resource in the course shown in transcripts in Tables 9 and 10.

Table 9

Transcript of Segment of Professor N's Introduction to the Course on Day 1 (Lines 98-116)

Line	Professor N
98	this workbook is something
	that I have put together for this class
100	it has problems from other textbooks
	or problems that I've written
	that apply the material
	that we are going to be covering
	this is a workbook that covers the entire term
105	and so when you print it out
	you can either print it all out
	at the beginning of the term
	or you can print it out in sections
	as we cover material
110	but I strongly recommend
	um
	doing problems in the workbook
	and then if you need extra
	going to the textbook
115	or visa-versa
	which ever works best for you

Table 10

Transcript of Segment of Professor N's Introduction to the Course on Day 1 (Lines 222-234)

Line	Professor N
222	I don't collect homework
	but like I said before
	you can't survive this class
225	unless you work on problems
	and you may have extra sheets (handouts)
	that I give to you to work in class
	or we might just work on the workbook problems
	its important that you print that out
230	and bring that with you to class
	because when I say
	ok
	we are going to do this problem
	you need to have that workbook in front of you

Where handouts were passed out to students and worked in class (Table 10, Lines 226-227), the workbook is a collection of problems that Professor N has collected or created (Table 9, Lines 98-101) for students to work problems in class (Table 10, Lines 228-234) and out of class (Table 9, Lines 110-116). Because Professor N emphasized the importance of doing problems (Table 10, Lines 224-225) and explained that she created this workbook and even designed some of the problems, she positioned doing problems as the means by which students will apply content in this class and the workbook as the primary resource for students to do this.

In this section, I identified and characterized the key events, such as lecture and doing workbook problems, by tracing patterns of activity and the variability in these patterns in order to make visible the principles of designing the events in this course as participants co-constructed activities within this studio learning environment. I also distinguished between lecturing as an activity and the lecture as an event. In the following section, I examine the patterns of activity within days to understand how and in what ways the key events of this course are integrated.

Research Question 1d. In what ways are lecture and lab "integrated" in this chemistry studio?

This studio classroom is often referenced as "integrated lab and lecture" in literature (Bailey et al., 2000), artifacts of the class (Neff, 2011), and in interviews with Professor N. Although I have already shown that lecture and lab are not the only distinct events in this class, the terms and meanings of "lab" and "lecture" are so entrenched in the academic chemistry (and other physical sciences) community that this vocabulary has been noticeably transferred to explain what is happening in this chemistry studio classroom. It is within the socio-historical frame of the traditionally separated lecture and lab (in space and time) that I argue how these events are transformed in this studio classroom.

On the first day of class, during her introduction of the course to the class, Professor N stated: "[E]ven though our class meets twice a week for 2 hours and 20 minutes, one of those days is a lab day, the other is what I call a lecture day" (Appendix E1, Lines 59-63). In order to show how and in what ways lecture and lab functions are "integrated", I explored what Professor N proposed to students as "typical" days, a "lecture day" (Day 4) and a "lab day" (Day 5), in the chemistry studio in her introductory lecture on Day 1. Like in previous analyses, data for this analysis is based in the actions and interactions of participants. These are represented in observation tables and event maps as discussed previously. Whereas the previous cycle of activity explored events across days and encompassed all classes up to the first exam (Days 1-9 in Figure), this analysis will focus in on a (sub) cycle of activity within this time period. Here, I focus on Day 4 and Day 5 (see Figure 12) as "telling cases" (Mitchell, 1984) of a "lecture day" (Day 4) and a "lab day" (Day 5).

These two days were also selected because together they constitute a cycle of activity where the concept of enthalpy, a thermodynamic property representing heat flow, was first introduced in Day 4 and built upon in lecture and workbook problem sessions such that students were provided access to the resources required for conducting the experiment on enthalpy of sublimation on Day 5. The continuity in content for Days 4 and 5 is shown in Appendix D.

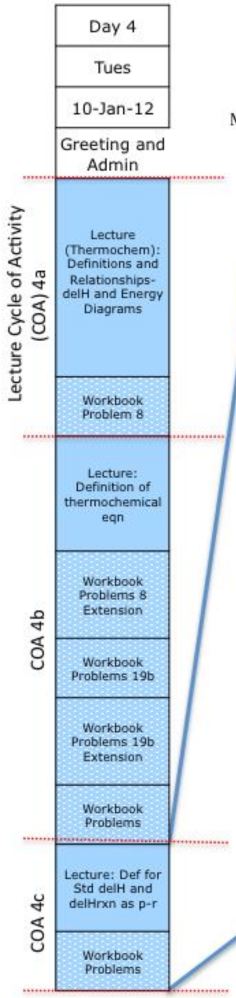
A lecture day. To help interpret cycles of activity on Day 4 in Figure 15, the references to patterns and expectations for lecture days are made visible in Professor N's dialogue with the class on Day 1 (Table 11).

Table 11

Transcript Segment (Lines 64-72) of Dialogue During Class on Day 1 Showing How the Professor Plans for Lecture Days

Line	Professor N (to whole class)
	I do not lecture for the entire 2 hours and 20 minutes
65	we would all go crazy if I did that
	I'd lose my voice
	and you guys would go to sleep
	so
	I tend to lecture in little increments
70	of about 30 minutes or so
	and then we stop and do some problems
	to apply what we have been talking about in the lecture

On Day 4 (see Figure 15), three lecture events (solid blue) were separated by one or more workbook problem events (dotted blue). The professor's dialogue in Table 11 explains how these events are connected. Lines 69-72 show that the instructor plans cycles of activity within the day to consist of lecture followed by workbook problems that "apply what we have been talking about in the lecture" (see Table 11, Line 72). This implies that lecture content is linked to the workbook content that comes after it. The content link between a lecture activity and the workbook problem(s) that come after it is explored in the pullout table in Figure 15. Based on actions in the observation table for Day 4 (see Appendix B) and examining the video records for this period, how time is spent by the collective in minutes 83 to 107 on Day 4 is represented in sequence units that explain what is happening during each phase of activity that make up the lecture and the workbook problem. Specifically, content in the lecture (using standard heats of formation to find heat of reaction) is then practiced by students in a workbook problem (using a table of standard heats of formation to find heat of reaction). Tracing content through lecture and workbook problems on Days 4 and 5 (see Appendix D) establishes this as a repeated pattern. Within this pattern, I identify a lecture followed by one or more problems (linked by content) as another level of cycle of activity. Day 4 is made up of three such cycles of activity consisting of a lecture followed by one or more workbook problems applying the lecture content. The cycles of activity at this level are separated with dotted lines in Figure 15. A series of these cycles made up of two types of events (lecture and workbook problems) connected in a chain of disciplinary



Pullout Table of a Lecture Cycle of Activity

Min	Events	Phases of Activity	Sequence Units
83	Event 1: Lecture: Standard enthalpies of formation	Introducing the concept of using standard enthalpy of formation to find standard enthalpies of reaction	P proposes content in a lecture activity: 1) conditions for standard state with regard to enthalpy of reaction and 2) defining and writing standard enthalpies of formation and 3) finding standard enthalpy of reaction as a function of the standard enthalpies of formation for products and reactants.
92		Demonstrating how to calculate heat produced using standard enthalpies of formation in an example of the reaction of ammonium nitrate and decane	P introduces example problem: asks how much heat is produced in a given reaction.
95			P models the process (in detail) of solving for heat using standard enthalpies of formation for products and reactants
			Reviewing solution and identifying what calculations are required for full or partial credit
97	Event 2: Doing WB #26	Problem posing: find heat produced	P introduces WB #26: asks how much heat is produced in a given reaction given table of standard enthalpies of formation
100		demonstrating balancing rxn	P demonstrates balancing the reaction to get it started. As last problem of the day, P says that students can stay for solution or leave. P observes collective for cues that they are done.
		students working independently/ groups	Students working independently and in partnered groups on problem. No one takes option of leaving.
105		reviewing solution	Reorienting as collective. P asking final solution and explaining path to solution.
107			

Photo A. Lecture characterized by professor's writing and explaining notes on an overhead projector that displays to all student computer monitors in real time.

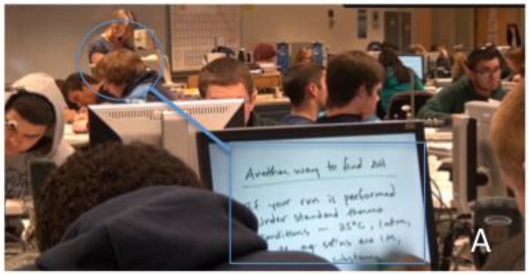


Photo B. Doing workbook problems affords opportunities for students to work on problems on their own and in groups. Here, two lab partnered groups discussing WB Problem#26 during a workbook problem session.

Figure 15. Overview of cycles of activity on Day 4 (Lecture Day). Photos A and B represent key characteristics of noted activities.

content characterizes what a “lecture” day may look like. An example of the phases of activity and sequence units of lecture and workbook problem events for one lecture cycle of activity are provided in detail in the pullout table in Figure 15.

Event 1: Lecture. In this lecture, Professor N introduced the concept of using standard enthalpies of formation for individual compounds to find the standard enthalpy of a reaction (see Figure 15, Frame Grab A). After explaining the concept, she demonstrated the concept in an example reaction (ammonium nitrate and decane) and provided a metadiscourse that made visible her thinking process in solving the problem.

Event 2: Workbook Problem. Professor N proposed that students do Workbook Problem #26 which gave students the opportunity to do the same type of problem that she had just demonstrated in the example in the lecture. However, this problem first required that students derive the reaction from the problem narrative and also provides a table of standard enthalpies of formation which is the common way of obtaining these values when doing these types of problems. So that students could focus on calculating the enthalpy of reaction and to minimize potential confusion, Professor N first guided students through deriving and balancing the reaction, a skill that had been covered in past disciplinary content. Then students worked independently and in groups as shown in Figure 15, Frame Grab B. As the last problem of the class period, Professor N proposed that students may depart class after they completed the problem, or they might stay to see her solution. When she saw that most students completed the work, she reoriented the class to the computer monitors and provided the solution in a lecturing function.

In doing workbook problems, students were given the opportunity to work with other students. In an interview, Professor N commented about the advantages of the table groups, which she called ‘circles’ in Table 12.

Table 12

Segment of Interview (13 Feb 2011) where Professor N Comments about Table Groups as a Collective Interactional Space

Line	Professor N
1	the thing that I like in the circles (tables)
	is that there is this big group (table group of 8 students)
	and they can look at each other
	they can talk to these people here (gesture to left)
5	and these people here (gesture to right)
	without moving
	they do not have to get up and move around
	they are just there

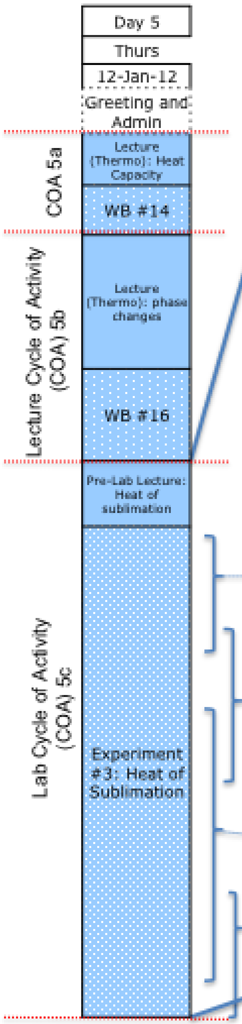
In Table 12, Professor N explained how the circular tables facilitated access between lab-partnered groups. Figure 16 shows what this communication looks like as members from three lab groups jointly discussed Problem 19 during a workbook problem session on Day 4.

A lab day. Exploration of the lab day in Figure 17 began much like the lecture day in that content is introduced within a lecture cycle of activity. Although the first ten minutes of class time is not available in the video records, the lecture notes show that the instructor began the lecture activity with the concept of heat

Figure 16. Frame grab showing access to peers in table group. Members of three lab-partnered groups are discussing a workbook problem during a workbook problem session on Day 4. Arrows show direction of eye gaze towards one student.

capacity. This concept relates the enthalpy change concept introduced in Day 4 to a temperature change which is the observable variable for this phenomena that will be examined in the lab. As such, the content in Day 5 was a continuation of the content from Day 4 (see Appendix D). The third cycle of activity (see Figure 17, Cycle of Activity 5c) was characterized by a lecture that introduced the lab (pre-lab lecture) followed by the laboratory event. The phases of activity and sequence units of the pre-lab lecture and the laboratory events as a lab cycle of activity are provided in detail in the pullout table in Figure 12. Phases of the pre-lab lecture are delineated by content.

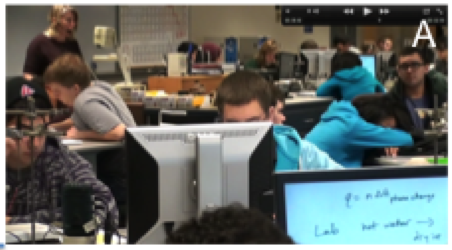
Event 1: Pre-Lab Lecture. In this pre-lab lecture, the professor outlined the specific chemistry content using the chemical substances, reactions, and equations that are required to do the lab. She also included key safety guidelines that are specific to this lab. The guidelines are built on safety guidelines that the professor proposed in her introduction to the course on Day 1 and other pre-lab lectures on Day



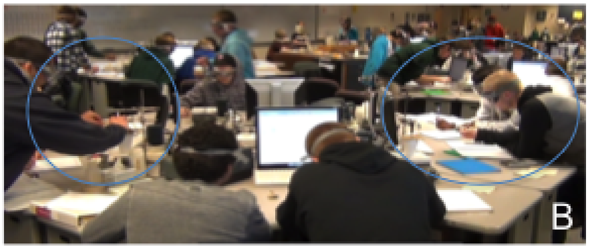
Pullout Table of a Lab Cycle of Activity

Events	Phases of Activity	Sequence Units	Min
Event 1: Pre-lab lecture: Heat of Sublimation	Presenting content for lab	Professor N explains heat transfer in sublimation (a phase change) through equations used in the lab. Heat capacity links amount of heat exchange with the observed temperature change. Prof N tells students to obtain data from other group members for statistical analysis.	38
	Reviewing lab procedures (analytical tools)	Professor N explains the experimental set up for coffee cup calorimetry and experimental assumptions. She also explains how to use the temperature probes and how to collect data through computer software (Logger Pro©)	
	Reviewing safety guidelines	Professor N explains safety concerns with the handling of dry ice.	
Event 2: Experiment #3: Heat of Sublimation	Setting up equipment	Prof N releases control of computers and students begin to obtain equipment and don goggles. Prof N announces over speaker system to to put out lab notebooks and get backpacks out of walkways. Students configure analytical equipment to obtain temp change using computer software. Professor N and TAs monitor student progress and addresses student questions.	43
	Conducting lab trials	Students weigh the dry ice and begin a trial obtaining temperature change of the water. Students do this three times. Professor N and TAs address student questions.	
	Organizing data and doing calculations	Students share data with other groups at their table. Prof N addresses student questions mainly with how to calculate heat exchange and about formatting of report.	
	Cleanup and turning in prelab	Students clean up their work areas and gather personal items, turn in pre-labs and depart the classroom.	124

Frame Grab A. During a pre-lab, Professor N writes and explains notes on a document camera that displays to all student computer monitors in real time.



Frame Grab B. Students make observations and conduct multiple trials at student tables.



Frame Grab C. Students check and share data with other lab partners within the table group.

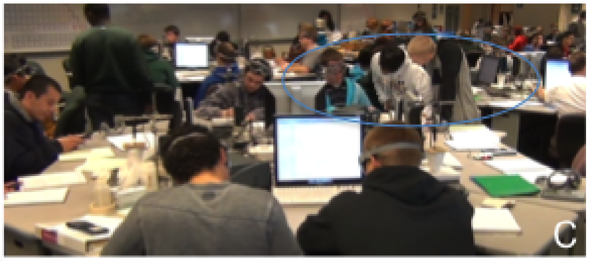


Figure 17. Overview of cycles of activity on Day 5 (Lab Day). Frame Grabs A, B, and C represent key characteristics of noted activities.

1 and Day 2. This pre-lab lecture (Day 5) focused on additional safety issues unique to this lab. Also, in this pre-lab lecture, the professor outlined the procedures involved in doing that lab to include new analytical techniques and guidance for obtaining “good” data. As shown in Frame Grab A (Figure 12), the pre-lab lecture activity occurs as a whole class with the instructor providing information in the same way as other lecture activities.

Event 2: Laboratory/Experiment. As shown in the observation tables for Day 5 (Appendix C1), the transition from the pre-lab lecture to the laboratory is a negotiation between the professor providing information in the pre-lab and students anticipating a start to the lab event. Just as the professor signaled the beginning of the whole class collective interactional space by taking control of the monitors, she did not release control of the monitors at the end of the pre-lab lecture until she was ready to handover responsibility of the lab to the students. Once again, control of the student computer monitors served as a signal of collective interaction and orientation on information provided by the instructor. Once the instructor released control of the monitors, student movement and movement about the room increased significantly. In these five seconds, the class transitioned from pre-lab activity to lab activity.

The experiment (or laboratory event) began approximately 44 minutes into the class time and ended when the last lab group departed the classroom 80 minutes later. Unlike the past identification of phases of activity in doing workbook problems (see Figure 15), the transitions between phases of activity within the laboratory event are more difficult to discern because students transition from phase to phase as lab partners and not collectively at the same time. So showing approximate times for collective transition is better represented as overlapping areas where some students are in one phase and some others have moved to the next. These overlapping areas are shown in Figure 17.

With thirty-two lab groups in different phases of lab activities, the lab event can be overwhelming for the outsider or an instructor new to the course. To help show what is it like to teach in this chemistry studio classroom for the first time, this professor shared some of her memories of that experience when she taught an organic chemistry lab in the chemistry studio as shown in Table 13.

It is highly unlikely that collective actions of students in lab changed from the professor's first experiences in the lab event. However, what has changed is how the instructor interpreted what was happening within the lab event. Also contributing to this initial perception of "utter chaos" in the lab event are the differences between what "lab" looks like in a traditional academic chemistry laboratory and in a chemistry studio. Whereas, traditional chemistry labs have lab partners lined up on long benches, the physical design of the studio does not promote the same sense of order. However, the studio design provides something that the traditional labs do not: an instituted collective space made of table groups. These table groups can function in various ways in the lab event as described by Professor N in Table 14.

In Table 14, Professor N also acknowledged the existence of table groups as a collective interactional space that she can use to disseminate information on how to *do* gas chromatography within the lab function. Figure 18 shows a series of still shots

Table 13

Segment from an Interview (conducted 13 Feb 2011) where Professor N Commented on her Initial Impressions about the Lab Event and How These Changed Over Time

Line	Professor N
1	with just you and one TA
	it can be really really chaotic during labs
	and I remember
	I'll never forget it
5	it was my first or second year teaching down there (in the chemistry studio)
	(Professor T) who started the studio and wasn't the chair yet
	her office was right next door to mine
	and I came up after a really rough lab
	and I said
10	and I think it was the organic chem lab
	which I really wasn't quite comfortable with yet
	and I said
	it was just so hard down there
	it was just utter chaos
15	and she says
	yeah
	isn't it fun/
	and I wanted to just crawl in my office and start crying
	and she says
20	yeah
	isn't it fun\
	and a couple of years ago
	I was walking around the lab
	and it was
25	I think it was an organic lab
	and everyone was engaged
	they were really working on what they were doing
	and I got caught up in it
	I was like
30	wow
	this is exciting
	everyone was engaged
	they were all doing something
	everyone was teaching each other
35	and I was running around
	and I was just loving it
	and I thought
	wow
	my perception
40	or my feelings about this
	had really changed

Table 14

Segment of Interview (13 Feb 2011) Where Professor N Commented about the Use of Table Groups as a Collective Interactional Space in the Lab Event

Line	Professor N
1	I think that group interaction is really helpful
	lots of times with the organic labs
	that are more technique intensive
	like when they are doing gas chromotography
	lots of times
5	I will show one pair how to do it
	and then I will say
	that they are responsible for showing others
	at their table
9	how to do it

during the phase in the lab where students organized data and did calculations. Within this phase of lab which required students to share data with other groups at their table, we see how the student, Joe, moved among the groups at his table to obtain data (Frame Grabs B and C) and conferred with more than one group at the same time (Frame Grab D). But we also see in Table 10 that Professor N believed that the table groups are beneficial because paired lab partners have convenient access to other paired lab groups at their table inside (Figure 18, Frame Grab B) and outside (Figure 18, Frame Grab C) of the lab function. This access to other partnered lab groups available both in lab and in lecture is also significant because, at least in the time period under study, groups maintained the same membership which can contribute to development of working relationships over time.

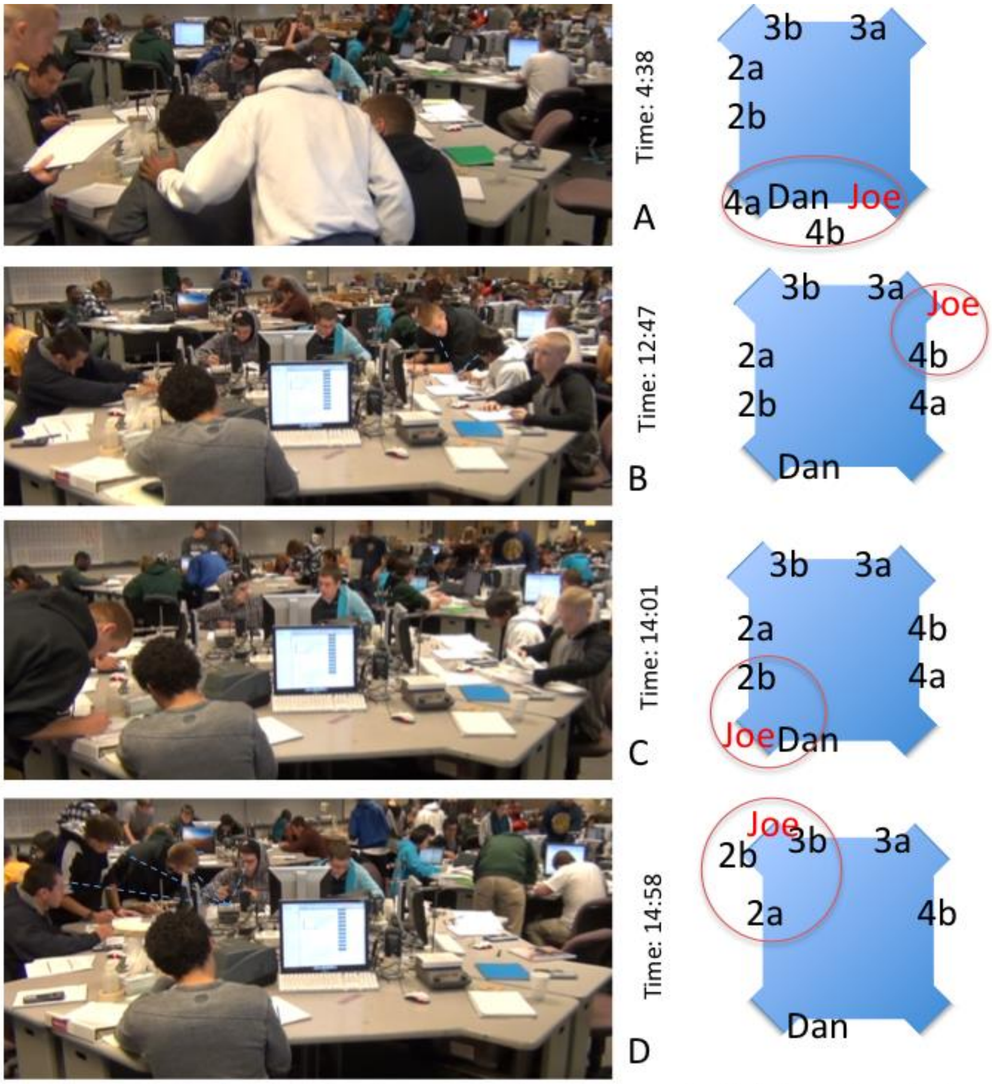


Figure 18. Frame grabs and schematics of location of table group members as groups checked data with each other as required by the lab. Note that Joe moved to various positions around the table (Photos B, C, and D) within two minutes.

Summary of findings from Research Question 1. This analysis of the first three weeks in the course characterized the patterns of activity that constitute the designing elements (events and activity) in this chemistry studio learning environment, such as lab, lecture, lecturing, and doing workbook problems. In contrast to traditional course structuring as lecture and lab, course structuring in this studio course is characterized by lecture and lab cycles of activity which are linked by disciplinary content. The key feature of the studio learning environment is the availability of the table and lab-group interactional spaces which were routinely accessed in both lecture and lab cycles of activity. These spaces afforded opportunities for students to use concepts and disciplinary practices proposed by Professor N (or a TA) in the lecturing activity. Within these spaces, students worked individually or in groups with access to peers, TAs, and Professor N as resources. Also, patterns in activity that characterized events were not static. Rather, these patterns varied dynamically by instructor and students acting and reacting to the situation in the moment.

Research Question 2. How did participants structure daily practices and processes in the **second** exam cycle of activity in comparison to the first exam cycle of activity

By examining the first exam cycle of activity (the first three weeks of the course) in Research Question 1 at the collective level of analysis and tracing how the instructor planned for the designing of instruction, I have shown what counts as specific key events, such as lab and lecture, and activity, such as lecturing and doing lab, in this undergraduate general chemistry course in a studio learning environment. Additionally, I have analytically described the various collective interactional spaces afforded in this class, again, within the 1st Exam Cycle of Activity.

This research question analysis extends the analysis of patterns of activity from the 1st Exam Cycle of Activity to the 2nd Exam Cycle of Activity in this course. As such, the purpose of the analysis in this section is to show how participants add to or change patterns of activity that characterize key events and activities for significantly different disciplinary content areas in this course: thermodynamics in the 1st Exam Cycle of Activity and quantum theory/atomic structure in the 2nd Exam Cycle of Activity.

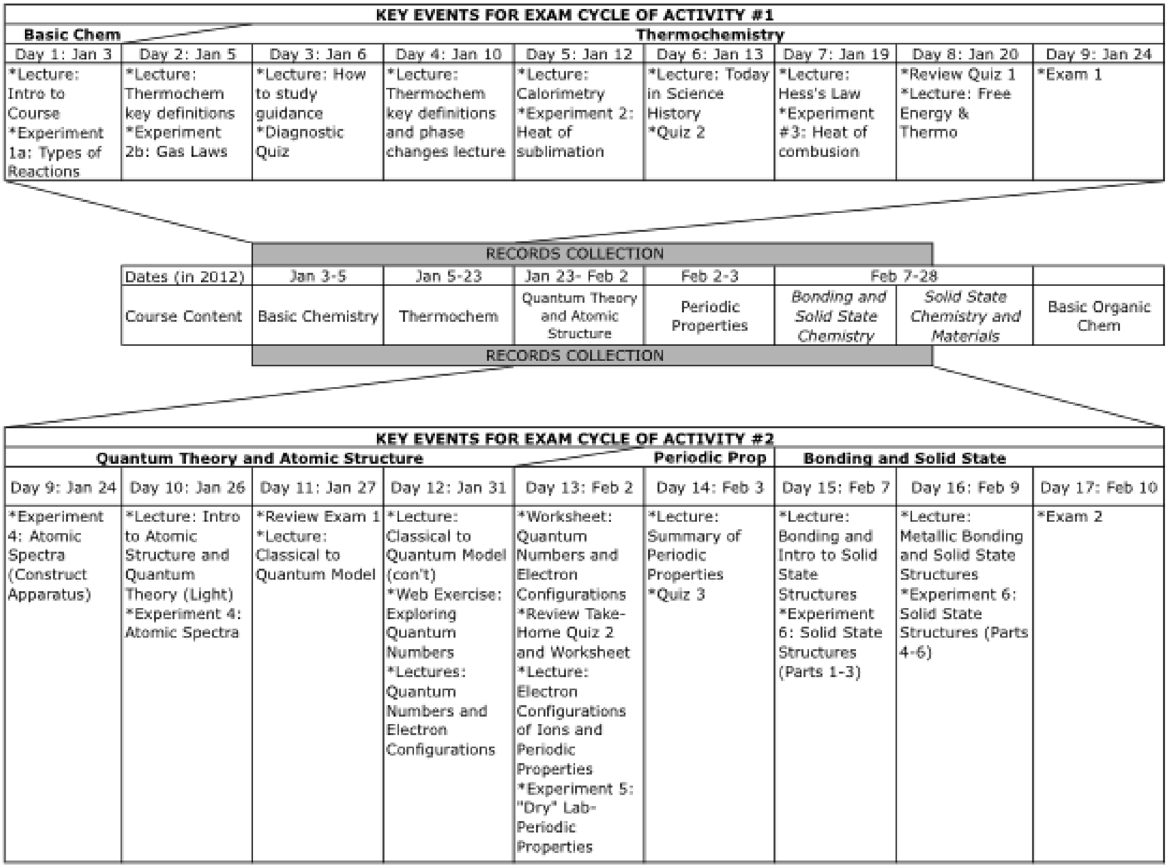
Specifically, this section examines the 2nd Exam Cycle of Activity consisting of weeks 4 to 6 of the ten-week course within the same conceptual framework and as discussed in Chapter II and general methodology from Chapter III. Additionally, some consideration is given to possible influences that the nature of the disciplinary content could have on structuring differences between the 1st and 2nd Exam Cycle of Activity. Furthermore, this section provides summarizing data for reference in exploring problem solving practices in Chapter V.

The logic of inquiry for the analysis of the 2nd Exam Cycle of Activity is shown in Figure 8b. The methodology is shown in Table 1. The methodology used to answer research questions 2a, 2b, and 2c are nearly identical to the methodology used in Research Question 1 (1a, 1b, and 1c).

Research Question 2a. In what ways is time spent in collective activity in the 2nd Exam Cycle of Activity?

This section analyzes how time was spent in collective activity for the 2nd Exam Cycle of Activity mainly by comparative analysis with the 1st Exam Cycle of Activity. Figure 19 shows key collective events by disciplinary content area and day.

The 2nd Exam Cycle of Activity encompasses nine class periods over three weeks. These are weeks 4, 5, and 6 of the ten week course. Whereas the 1st Exam Cycle of Activity introduced one content area, thermodynamics, the 2nd Exam Cycle of Activity covers several topics: atomic structure and quantum mechanics, periodic properties, and bonding with an introduction to solid state chemistry. Recall from Chapter III that solid state chemistry is not typically found in a General Chemistry curriculum and is not included in the general chemistry course for science majors at this university (Neff, Personal interview, February 9, 2011). However, this topic was included for the engineering majors course because of the relationship between atomic structure of solid materials and their physical characteristics (malleability, ductility, etc.) which is of particular interest to the engineering discipline. Many of the same event structures (lecture, lab, reviews, exams, quizzes) from the 1st Exam Cycle of Activity were also found in the 2nd Exam Cycle of Activity. Characterizing elements of “new” events co-constructed in the 2nd Exam Cycle of Activity will be discussed in the following sections.



KEY EVENTS FOR EXAM CYCLE OF ACTIVITY #1

Basic Chem	Thermochemistry							
Day 1: Jan 3	Day 2: Jan 5	Day 3: Jan 6	Day 4: Jan 10	Day 5: Jan 12	Day 6: Jan 13	Day 7: Jan 19	Day 8: Jan 20	Day 9: Jan 24
*Lecture: Intro to Course *Experiment 1a: Types of Reactions	*Lecture: Thermochem key definitions *Experiment 2b: Gas Laws	*Lecture: How to study guidance *Diagnostic Quiz	*Lecture: Thermochem key definitions and phase changes lecture	*Lecture: Calorimetry *Experiment 2: Heat of sublimation	*Lecture: Today in Science History *Quiz 2	*Lecture: Hess's Law *Experiment #3: Heat of combusion	*Review Quiz 1 *Lecture: Free Energy & Thermo	*Exam 1

RECORDS COLLECTION

Dates (in 2012)	Jan 3-5	Jan 5-23	Jan 23- Feb 2	Feb 2-3	Feb 7-28		
Course Content	Basic Chemistry	Thermochem	Quantum Theory and Atomic Structure	Periodic Properties	*Bonding and Solid State Chemistry*	*Solid State Chemistry and Materials*	Basic Organic Chem

RECORDS COLLECTION

KEY EVENTS FOR EXAM CYCLE OF ACTIVITY #2

Quantum Theory and Atomic Structure					Periodic Prop	Bonding and Solid State		
Day 9: Jan 24	Day 10: Jan 26	Day 11: Jan 27	Day 12: Jan 31	Day 13: Feb 2	Day 14: Feb 3	Day 15: Feb 7	Day 16: Feb 9	Day 17: Feb 10
*Experiment 4: Atomic Spectra (Construct Apparatus)	*Lecture: Intro to Atomic Structure and Quantum Theory (Light) *Experiment 4: Atomic Spectra	*Review Exam 1 *Lecture: Classical to Quantum Model	*Lecture: Classical to Quantum Model (con't) *Web Exercise: Exploring Quantum Numbers *Lectures: Quantum Numbers and Electron Configurations	*Worksheet: Quantum Numbers and Electron Configurations *Review Take-Home Quiz 2 and Worksheet *Lecture: Electron Configurations of Ions and Periodic Properties *Experiment 5: "Dry" Lab- Periodic Properties	*Lecture: Summary of Periodic Properties *Quiz 3	*Lecture: Bonding and Intro to Solid State Structures *Experiment 6: Solid State Structures (Parts 1-3)	*Lecture: Metallic Bonding and Solid State Structures *Experiment 6: Solid State Structures (Parts 4-6)	*Exam 2

Figure 19. Timeline pullout of key events in the 1st and 2nd Exam Cycle of Activity in the General Chemistry for Engineering Majors course within a studio learning environment.

Figure 19 shows how time was spent in the second exam cycle of activity of the course. These events were constructed using the same ethnographic conceptual frameworks (Green, Dixon, Zaharlick, 2003) and methods (Green & Wallat, 1981; Green & Meyer, 1991) that were used to construct the event map of the 1st Exam Cycle of Activity, Figure 12. Additionally, the logics used in determining events and activities from the 1st Exam Cycle of Activity were used as a resource to construct similar and additional events and activities in the 2nd Exam Cycle of Activity through comparative analysis.

Conceptually, this analysis reflects how actors construct their worlds. Many of the same structural elements that were constructed by instructor and students in the 1st Exam Cycle of Activity were used as a resource for structuring events in the 2nd Exam Cycle of Activity (Figure 19). Patterns of lecturing as an activity, lecture events, and lab events were constructed in much the same way as in the 1st Exam Cycle of Activity. Lecture events were between 20 to 50 minutes in duration and not restricted to lecture days. On a lecture day such as Day 4 (Figure 12) and Day 12 (Figure 20), the lecture events were interrupted by collective activities that required students to engage with content individually or in groups. On lab days such as Day 5 (Figure 12) and Day 13 (Figure 20), a lecture event provided the foundational disciplinary content prior to more specific guidance about the experiment within the pre-lab lecture event. Within lab events, the instructor continued to provide additional information and guidance, if she deemed necessary, in a continuation of the pre-lab lecture one-half (Figure 20, Day 10) to two-thirds (Figure 20, Day 13) of the

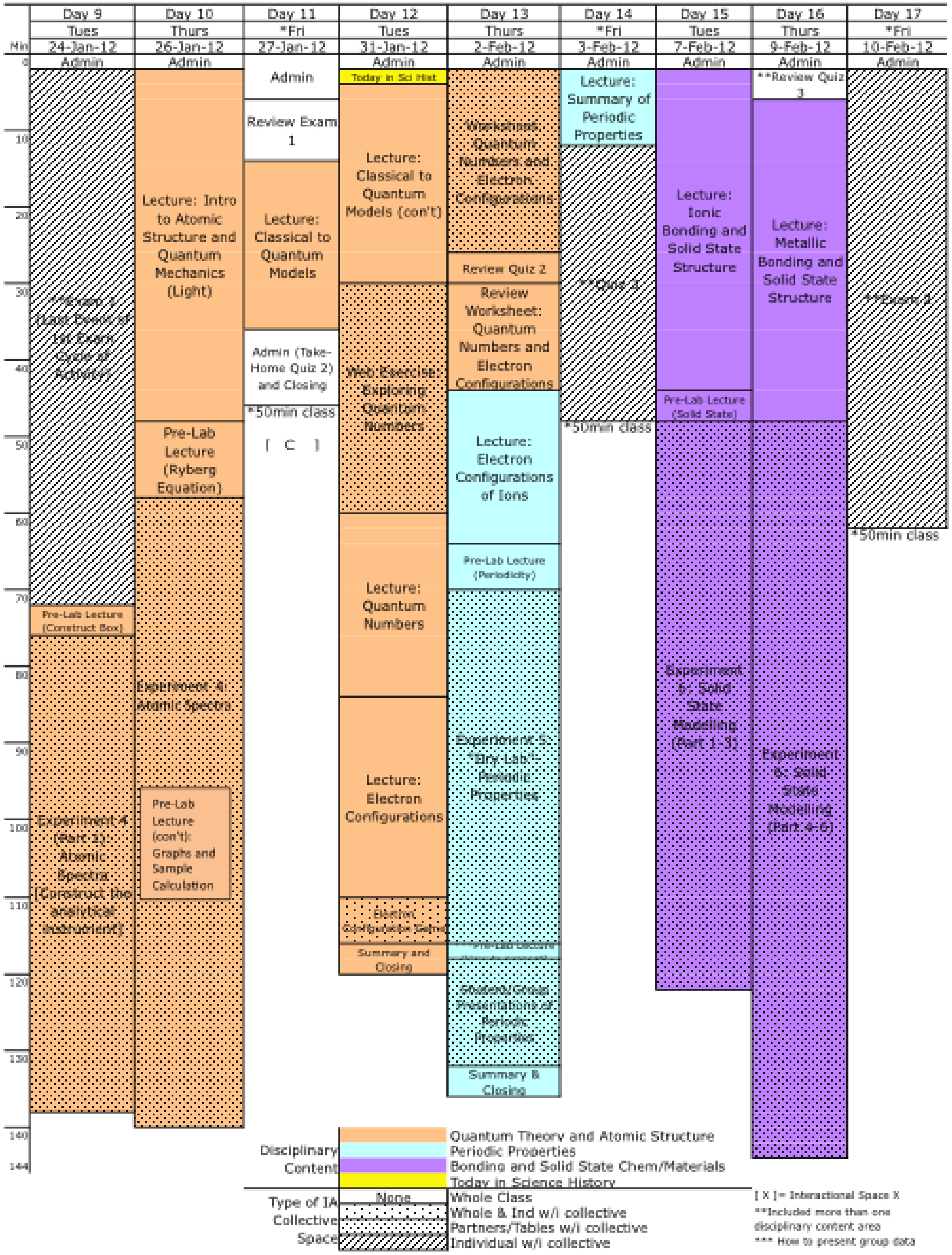


Figure 20. Event map showing how time was spent in the 2^{nd} Exam Cycle of Activity for Days 9-17.

time into the experiment. Assessments were conducted during the 50-minute period on Fridays (Figure 20, Days 14 and 17) much like was shown in the 1st Exam Cycle of Activity (Figure 20, Days 3 and 6).

Despite all the similarities in events, there were also several notable differences between the two exam cycles of activity. First, the 2nd Exam Cycle of Activity did not include workbook problems. Second, the 2nd Exam Cycle of Activity included two events not present in the 1st Exam Cycle of Activity: a web exercise on exploring quantum numbers and an electron configuration game on Day 12. So although many of the same structuring elements were present in the 2nd Exam Cycle of Activity, these differences suggest that content may be constructed by participants in slightly different ways and which is shown in the variability of collective activity.

Research Question 2b. In what ways does collective activity in the second exam cycle of activity contribute to how key events and activities are characterized?

Table 15 shows the types of key events of the course and their characterizing activities for the cycle of activity under study. Table 15 was constructed by adding events and activity contributions from the 2nd Exam Cycle of Activity to Table 4 using the same conceptual framework and methods used to construct Table 4. These additions are indicated with bold type in Table 15. Collective activities that characterize each event are annotated with an ‘x’ for each day that the activity occurred as determined from the observation tables (Days 9-17). As explained in detail in Research Question 1, the significance of this table is that it shows how the students and instructor co-constructed similar patterns of actions and interactions within an event. These experiences then became a common resource that built common understandings of "how things are done around here" including roles and relationships, rules and obligations, and norms and expectations for future events of the same type. The table shows events characterized as patterns of activity where events do not occur with the same activities every time. Rather, there is variability in what counts as an event such as lab or lecture.

Analysis of patterns of activity. Analysis of Table 15 shows that one event has been added to the list of events in this class from the 2nd Exam Cycle of Activity: the web exercise. The web exercise occurred on a lecture day (Table 15 and Figure 20, Day 12) where, after the professor provided guidance for doing the exercise, students used internet resources on their own to obtain new information (declarative knowledge) about quantum numbers.

Additionally, in accordance with Table 4, several activities within events (identified in bold type) have been added from observation tables from the 2nd Exam Cycle of Activity that further expand what may constitute (or count as) an event. For example, unlike previous lecture events, on Day 12 (Table 15) the instructor provided disciplinary content about how quantum number content is conceptually structured while drawing on declarative knowledge acquired by students rather than having been provided by Professor N.

Again, this table shows how what counts as a specific type of event (e.g., lab, lecture) is co-constructed by participants over class periods. More broadly, this table shows what opportunities for learning, through class events and activity, were made

Table 15

Patterns of Activity for the 1st and 2nd Exam Cycles of Activity

Note: **Bold** events and activities are added from 2nd Exam COA

	1st Exam Cycle of Activity								2nd Exam Cycle of Activity								
Event	Day																
Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Using speaker system when addressing whole class	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Greeting and Admin	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
P taking control of student computers to display information	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x
Announcing brief administrative details about schedule/plan	x	x	x	x	NA	x	x	x	x	x	x	x	x	x	x	x	x
Providing guidance for key aspects of the course (w/control of display)	x		x	x			x										
Explaining how lecture occurs	x																
Orienting to computer resources	x																
Explaining how to do workbook problems in class	x																
Providing guidance for doing problems outside of class	x			x													
Explaining what students should know already (from HS)	x																
Explaining safety guidelines for lab (general for all labs)	x																
Providing guidance for studying, negotiating problems, taking notes	x		x														
Providing guidance for pre-lab, lab report/conclusion				x													
Providing guidance about preparing for exam							x										
Review of student work- providing collective feedback and focusing on select content								x			x		x				
From an Assessment: quiz or exam								x			x		x				
From an In-class Worksheet													x				
Lecture: Today in Science History						x						x					
Quiz or Exam			x			x			x					x			x
Orienting to quiz/exam materials and admin for quiz/exam			x			x			x					x			x
Quiz or Exam: Students taking an individual assessment			x			x			x					x			x
Lecture (With control of display)	x	x		x	x		x	x			x	x	x	x	x	x	
Transitioning to new content by linking to past content					NA		x	x			x	x		x	x	x	
Providing disciplinary content structure drawing on declarative knowledge acquired by students in a class exercise (Quantum Numbers)												x					
Providing disciplinary content- definitions, equations, and structure	x	x		x	x		x	x			x	x		x	x	x	
Solubility rules	x	x															
Nomenclature	x	x															
Thermochem- forms of energy and heat definitions		x		x													
Internal energy, energy diagrams, combustion reaction				x													

Table 15

Patterns of Activity for the 1st and 2nd Exam Cycles of Activity

Note: **Bold** events and activities are added from 2nd Exam COA

Event																	
	1st Exam Cycle of Activity									2nd Exam Cycle of Activity							
	Day																
Activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Lecture (con't)	x	x		x	x		x	x			x	x	x	x	x	x	
Thermochemical equations				x													
Enthalpy/Standard heat of reaction				x													
Heat capacity, phase changes, heating curve					x												
(continued on next page)																	
Providing disciplinary content- definitions, equations, and/or structure (con't)	x	x		x	x		x	x			x	x		x	x	x	
Hess's law							x										
Entropy and Free energy								x									
Light										**x**							
Classical to quantum models											**x**	**x**					
Wave Particle duality of light											**x**						
Heisenbergy Uncertainty Principle, Schrodinger Equation												**x**					
Quantum numbers												**x**					
Electron Configurations												**x**					
Electron Configurations of Ions													**x**				
Bonding and Solid State Structures															**x**		
Metallic Bonding and Ionic Solid Structures																**x**	
Providing disciplinary content- applying concepts in examples	x	x		x	x		x	x		x	x	x	x		x	x	
Non-workbook example calculation											x	x			x	x	
Explaining content with demonstration or artifact				x												x	
Using handwarmers to show exothermic reaction				x													
Using broken metal bars to show properties of metals																x	
Using a handout to help students engage with qualitative content							x	x									
P leading students through problem(s)							x	x									
Providing metadiscourse on finding solution							x	x									
Obtaining student feedback in getting to solution							x	x									
Using a handout for student note taking for qualitative content (has diagrams)															**x**	**x**	
Using historical context as primary vehicle to link content										**x**	**x**	**x**					
Doing a Class Activity (Electron Configuration game)												**x**					
Workbook Problems (Content reflects lecture content)				x	x				x								

Table 15

Patterns of Activity for the 1st and 2nd Exam Cycles of Activity

Note: **Bold** events and activities are added from 2nd Exam COA

Event	Activity																	
		1st Exam Cycle of Activity																
										2nd Exam Cycle of Activity								
		Day																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	Providing problem number and context				x	x				x								
	Involving doing a calculation				x	x				x								
	Students working individually or in groups on problem(s)				x	x												
	P leading students through problem(s)					x				x								
	Releasing computer control to students as they work the problem				☐													
	Providing metadiscourse on finding solution				x	x				x								
	Obtaining student feedback in getting to solution				x	x				x								
Web Exercise (Exploring Quantum Numbers)													x					
	Providing guidance for doing the exercise												x					
	Students obtaining new information from internet resources												x					
Pre-Lab Lecture (with control of display)		x	x			x		x		x	x			x		x	x	
	Explaining requirements and guidelines for lab reports	x																
	Reviewing disciplinary content for todays lab	x	x			x		x		x	x			x			x	
	Types of reactions: discern type and formula (nomenclature)	x																
	Gas Laws: find R from P, V, T		x															
	Stoichiometry		x															
	Heat of sublimation: finding heat transfer in phase change					x												
	Hess's Law: finding enthalpy for combustion reaction using Hess's law							x										
	Intro to atomic spectra and constructing the box (analytical tool)									x								
	Atomic Spectra - Ryberg Equation										x							
	Periodicity and Periodic Properties													x				
	Ionic Solid State Structures																x	
	Orienting students to bench and instrumentation available	x	x															
	Explaining online location of procedures	x	x			x												
	Reviewing analytical (experimental) procedures of today's lab	x	x			x		x		x	x			x		x	x	
	Reviewing safety procedure for today's lab	x	x			x		x			x			x		x		
	Requiring students to obtain or check data from other groups					x								x				
	Releasing computers to transition to lab	x	x			x		x		x	x			x		x	x	

Table 15

Patterns of Activity for the 1st and 2nd Exam Cycles of Activity

Note: **Bold** events and activities are added from 2nd Exam COA

Event / Activity	1st Exam Cycle of Activity									2nd Exam Cycle of Activity							
	Day																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Lab/Experiment (content reflects that of Pre-lab lecture or prior Lecture event)	x	x			x		x		x	x			x		x	x	
Students setting out pre-labs					x		x			x							
Making lab related announcements/guidance as needed	x	x			x		x		x	x			x		x	x	
Students obtaining materials and don safety equipment	x	x			x		x		x	x					x	x	
Students construct the analytical apparatus									x								
Students conducting lab	x	x			x		x			x			x		x	x	
Making and recording observations from TA demonstration	x																
Making and recording observations (qual)	x	x													x	x	
Taking and recording measurements (quant)		x			x		x			x					x	x	
Obtaining values (data points) from online resources													x				
P lecturing on content within the lab (w/student display control)	x	x								x						x	
reviewing specifics about nomenclature rules and solubility	x																
reviewing calculation in finding pressure		x															
Reviewing calculation and explaining how to make the graph										x							
Showing diagrams of the unit cell for clarification																x	
Students working with their data (analysis)	x	x			x		x			x			x		x	x	
Students presenting information as a group to the class													x				
Students cleaning area, putting away safety gear	x	x			x		x		x						x	x	
Students turning in prelabs					x		x									NA	
Students keeping prelabs to turn in with lab										x						NA	
Closing remarks giving admin guidance	x	x	x	x	x			x		x	x	x	x				
Releasing student computers								x									
Students departing individually following required tasks			x		x	x	x		x						x	x	x

available to the collective as a result of actions and interactions co-constructed by instructor, TAs, and students. However, this table does not show how this instructor designs for new events within the flow of instruction.

Research Question 2c. In what ways do patterns in activity and events make visible principles for designing this course in the studio classroom in the 2nd Exam Cycle of Activity?

As shown previously, in order to make visible additional principles in designing the course from the 2nd Exam Cycle of Activity, this analysis focuses on how select cycles of activity and events contribute to understanding how this course functions.

During an informal interview (Table 16) with the instructor following class on Day 11 (Interactional Space C, Figure 19), Professor N commented about the transition between the two exam cycles of activity, generally, and the two disciplinary content areas of thermodynamics (1st Exam Cycle of Activity) and quantum theory and atomic structure (2nd Exam Cycle of Activity). In Table 16, Professor N explained her difficulty in moving from the first exam cycle of activity to the second because of moving from the macroscopic world of thermodynamics (observable in common experience of physical processes) to the subatomic (microscopic) world of quantum theory and atomic structure (Table 16, Lines 15-22) where the only connection is energy (Table 16, Line 23). Her desire to make the transition “a more consistent story” (Table 16, Line 5) in linking the thermodynamics content with the quantum theory and atomic structure content suggests that constructing content as a

Table 16

Transcript Section Showing Professor N Commenting to Researcher (Figure 19, Interactional Space C) about Transitioning from the 1st to the 2nd Exam Cycle of Activity

Line	Professor N
1	we've (Professor N and another instructor) been talking about rearranging the material
2	and
3	trying to figure out how to make it
4	like a better
5	a more consistent story
6	and
7	I love this material
8	but I think every time I teach it (quantum theory)
9	still
10	I flub
11	at the beginning
12	because it's just so
13	disconnected
14	from what I've been talking about before (thermodynamics)
15	'cause I've gone from the macroscopic
16	where I'm talking about heat
17	and you know
18	very physical processes
19	that are a little easier
20	I think
21	to understand
22	and now we are going down to the subatomic world
23	and the only connection is energy
24	which is a good connection
25	but it's just
26	it's like this
27	big jump
28	and after this
29	we don't make a big jump like that

"story" is a fundamental principle in the designing instruction for this course. Professor N's concern about engaging with content at the macroscopic level and then making a "jump" (Table 16, Lines 26-29) to the microscopic level suggests that there may be fundamental differences in the nature of the content between the 1st and 2nd

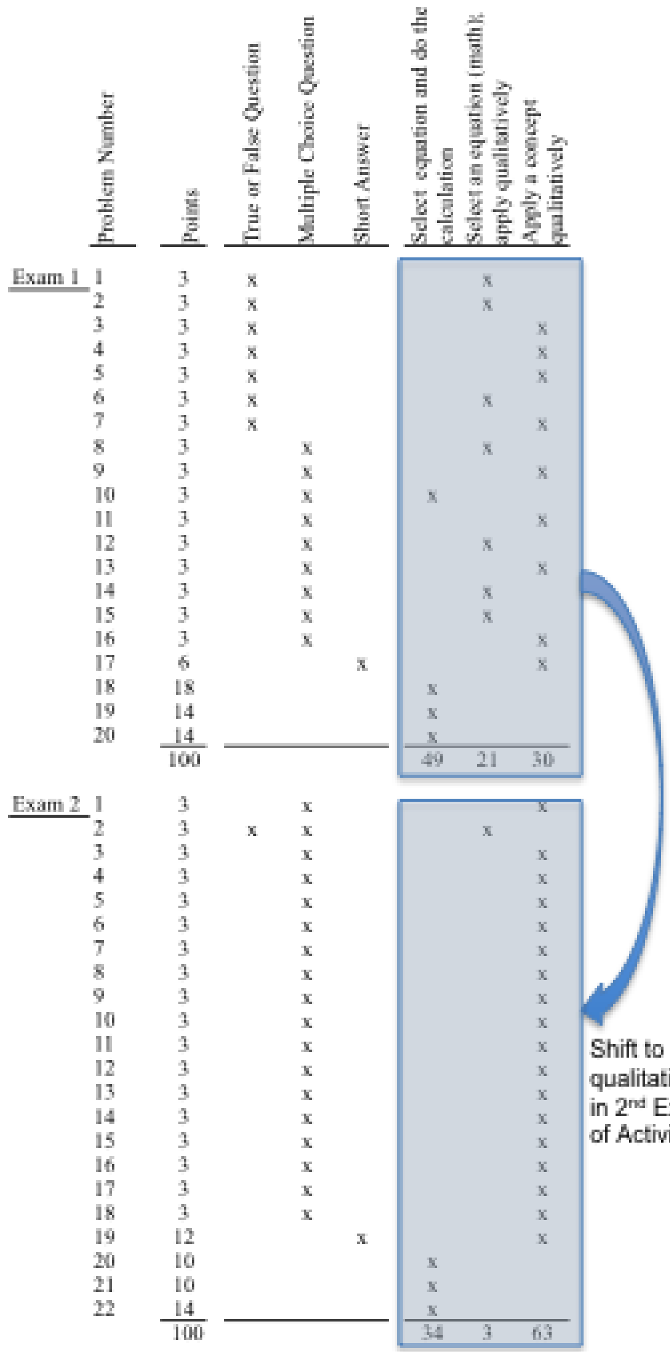
Exam Cycles of Activity that influence patterns of activity in this class. In referring to the nature of the content for the purposes of this study, this means the extent to which the concept is presented and applied within a mathematic equation (e.g., requiring a calculation) or presented and applied in a more qualitative way (e.g., requiring symbolic representation and/or interpretation).

Comparative analysis of Exams 1 and 2. In order to very generally assess the differences in the nature of the content between the 1st and 2nd exam cycles of activity, the exams from both exam cycles of activity (Days 9 and 17) were compared in Table 17a. This analysis is based on the assumption that the disciplinary content in the exams is representative of the disciplinary knowledge that students are expected to know. In this way, what is required of the student in showing what counts and an answer is an implicit expectation of what is required to do general chemistry in this course.

The exams are available in Appendix G for cross-referencing the question number with exam question. Structurally, each exam is divided into two parts (see Appendix G) based on the requirement for providing a solution to the problem. The true/false and multiple choice questions are graded by SCANTRON® and constitute Part 1 of each exam. Part 2 of each exam requires either providing a short answer or showing all work in a word problem with calculation. Of the 20 questions in Exam 1, three are short answer or calculation. Similarly, of the 22 questions in Exam 2, three are short answer or calculation.

Table 17a

Comparative Analysis of Exams 1 and 2



	Problem Number	Points	True or False Question	Multiple Choice Question	Short Answer	Select equation and do the calculation	Select an equation (math); apply qualitatively	Apply a concept qualitatively
Exam 1	1	3	x				x	
	2	3	x				x	
	3	3	x					x
	4	3	x					x
	5	3	x					x
	6	3	x				x	
	7	3	x					x
	8	3		x			x	
	9	3		x				x
	10	3		x		x		
	11	3		x				x
	12	3		x			x	
	13	3		x				x
	14	3		x			x	
	15	3		x			x	
	16	3		x				x
	17	6			x			x
	18	18				x		
	19	14				x		
	20	14				x		
		100				49	21	30
Exam 2	1	3		x				x
	2	3	x	x			x	
	3	3		x				x
	4	3		x				x
	5	3		x				x
	6	3		x				x
	7	3		x				x
	8	3		x				x
	9	3		x				x
	10	3		x				x
	11	3		x				x
	12	3		x				x
	13	3		x				x
	14	3		x				x
	15	3		x				x
	16	3		x				x
	17	3		x				x
	18	3		x				x
	19	12			x			x
	20	10				x		
	21	10				x		
	22	14				x		
		100				34	3	63

Shift to more qualitative content in 2nd Exam Cycle of Activity

Table 17a characterizes each question number by points allocation, and question type (true/false, multiple choice, short answer). The three categories that characterize the nature of the content represent a qualitative interpretation of the extent to which the solution requires qualitative versus quantitative consideration. These categories were derived deductively upon analysis of the exams to construct Table 17b based on what a student must "do" to reach a solution. The categories are: 1) select equation and do calculation, 2) select equation and apply qualitatively, and 3) apply a concept qualitatively. An example of each problem type is shown in Table 17b. In Table 17a, the point total out of 100 is shown for each of these categories for each exam.

Analysis of Table 17a shows that there is a 33 point increase in qualitative-based questions (applying a concept qualitatively) from Exam 1 to Exam 2. This evidence suggests that the transition from thermodynamics to quantum mechanics is not only a shift from the macroscopic to the microscopic, but also from the more quantitative to qualitative nature of the content at the level that it is presented in this course. This shift from concepts as mathematical representations in Exam 1 to qualitative-based concepts is represented in Tables 17c and 17d for Exams 1 and 2, respectively, showing the number of problems by question format and performance expectations. In order to explore possibilities in how content and other structuring elements manifest in the designing of instruction for this flow of activity, the next section will explore these issues within a select cycle of activity delineated by content area.

Table 17b

Examples of Problem Categories for Performance Expectations

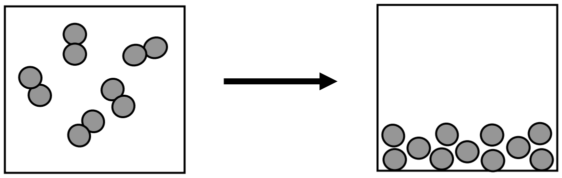
Performance Expectations	Example (all from Exam 1) and Solution Path
Select equation and do calculation	(Exam 1) 20. Find the ΔH_{rxn} for the reaction $C_5H_{12}(\ell) \rightarrow 5\,C(s) + 6\,H_2(g)$ using the information given below. Show all your work explicitly for full credit!! $5\,CO_2(g) + 6\,H_2O(g) \rightarrow C_5H_{12}(\ell) + 8\,O_2(g)$ $\Delta H = +3505.8$ kJ $CO_2(g) \rightarrow C(s) + O_2(g)$ $\Delta H = +393.5$ kJ $2\,H_2(g) + O_2(g) \rightarrow 2\,H_2O(g)$ $\Delta H = -483.5$ kJ Solution Path: 1) Select appropriate equation from list of equations on exam: $\Delta H^o rxn = \Sigma\, n\, \Delta H^o f$ products - $\Sigma\, n\, \Delta H^o f$ reactants 2) Use ΔH's as appropriate to calculate $\Delta H^o rxn$.
Select an equation and apply qualitatively	(Exam 1) 6. (True or False) For an adiabatic process (one which has q= 0) that does work on the surroundings, the total internal energy $\Delta E > 0$ Solution Path: 1) Recall and apply appropriate equation: $\Delta E = q + w$ 2) Substitute q=0 and account for sign convention for work
Apply a concept qualitatively	(Exam 1) 16. Consider the process shown here:  What signs would you **predict** for ΔH and ΔS for this process? a. +ΔH,+ΔS b. –ΔH,+ΔS c. -ΔH, -ΔS d. +ΔH, -ΔS Solution Path: Apply physical meaning of enthalpy (ΔH) and entropy (ΔS) in this representation and account for the sign conventions.

Table 17c

Question Format by Performance Expectations in Exam 1 (20 Questions)

Question Format	Performance Expectations		
	Select and equation and do the calculation	Select and equation and apply qualitatively	Apply a concept qualitatively
True/False	0	3	4
Multiple Choice	1	4	4
Short Answer	0	0	1
Word Problem	3	0	0
Total	4	7	8

Table 17d

Question Format by Performance Expectations in Exam 2 (22 Questions)

Question Format	Performance Expectations		
	Select and equation and do the calculation	Select and equation and apply qualitatively	Apply a concept qualitatively
True/False	0	1	0
Multiple Choice	0	0	17
Short Answer	0	0	1
Word Problem	3	0	0
Total	3	1	18

Designing for the quantum theory and atomic structure cycle of activity. Each content area is a cycle of activity (Green & Wallat, 1981) linked by content. In this section, I will explore how and in what ways the instructor designed for quantum theory and atomic. This content cycle of activity was selected for analysis because it covered more than half of the time spent in the 2nd Exam Cycle of Activity (see Figure 19). Examining this cycle of activity would be conducive to making the patterns in activity visible as these develop over time within the same content area. Additionally, Professor N made direct reference to how this content area (quantum theory) differs from thermodynamics making this content area of particular interest (Table 16). Therefore, I expected that analysis of this cycle of activity would make visible additional design features more so than the cycles of activity in the remainder of the 2nd Exam Cycle of Activity covering periodic properties and bonding and solid state structures. Furthermore, the analysis of problem solving practices in Chapter V is based on this content area.

The quantum theory and atomic structure cycle of activity began on Day 9 (see Figure 19) as students constructed the analytical instrument for the atomic spectra lab on Day 10 and ended with a review of quantum numbers and electron configuration on Day 13. It consisted of several lecture events, three review events, and one lab event like those in the 1st Exam Cycle of Activity (Table 4) with additional variability contributed from the 2nd Exam Cycle of Activity documented in Table 15. Additionally, it included a web exercise event which was introduced for the first time in the course.

It should be noted here that the quantum theory and atomic structure cycle of activity did not follow the typical weekly flow of activity as described by Professor N. On Day 1, Professor N explained that a typical week consisted of two longer lecture or lab days and a graded assessment, quiz or exam, on Fridays as shown in Figure 12. However, because of a holiday schedule change, the class did not meet on Tuesday of the third week of class (Figure 12). As a result, the instructor lectured on entropy and free energy on a Friday and pushed the first exam to the following week. This suggests that in the designing of instruction, it is more important to maintain content continuity in the flow of activity than disrupt the preferred event schedule, in this case, administering a 50-minute exam in the Friday 50-minute class period.

This delay extended into quantum theory and atomic structure cycle of activity. On Day 11, Professor N referenced this delay in her administrative announcements in the beginning of class:

Table 18

Transcript Selection Showing Professor N Announcing (Beginning of Day 11) to the Class Her Plan for the Designing of Instruction for Days 11 and 12

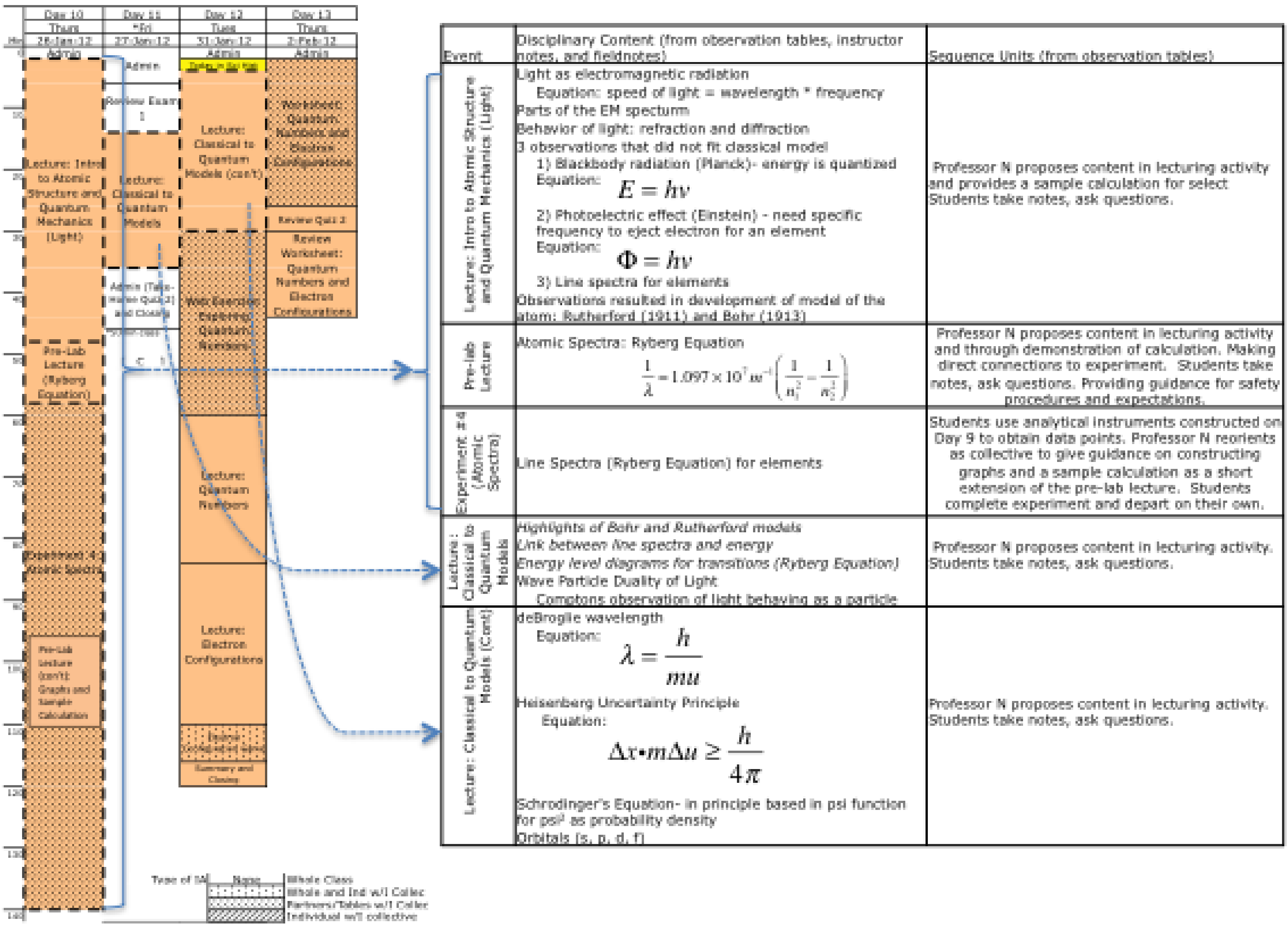
Line	Professor N
[01-26 09;27;28 at 5:45]	
1	the quiz tomorrow [Day 12, Friday] is going to be take home
2	because again
3	we're still
4	a little behind
5	and I couldn't see lecturing today
6	and then testing you right away
7	on what I lecture
8	today
9	so
10	it'll be take home
11	and we will have lecture tomorrow
12	as well as
13	I'll pass back the exam
14	and we'll probably go over
15	a little bit of the exam

Table 18 shows that rather than doing a quiz on Day 11, a Friday, Professor N planned to lecture on quantum models and adjusted the quiz such that the students did it outside of class time. In designing for this course, Professor N's decision to do a take-home quiz makes visible that maintaining the schedule of disciplinary content (or in this case, adjusting to re-establish her planned schedule for proposing disciplinary content) is a higher priority for class time than a quiz event. Furthermore, this shows that the completion of planned course content for the course is a fundamental principle for designing instruction.

In order to examine how the quantum theory and atomic structure (QT/AS) cycle of activity is constructed by event, Figures 21a and 21b were constructed to highlight select portions of this content cycle of activity for more detailed analysis. Note that events such as administrative and review events that did not cover this content area were not included for detailed analysis. Additionally, Part 1 of the atomic spectra lab conducted on Day 9 was not included for detailed analysis because constructing the analytical instrument was an procedural task void of disciplinary content. Therefore, only quantum theory and atomic strucutre content from Days 10-13 is shown in Figures 21a and 21b.

Figures 21a and 21b include pullouts of each event showing disciplinary content and sequence units. These pullouts were constructed from the instructor's lecture notes (that she wrote and displayed on the document camera to student computer monitors during lecture events), observation tables and researcher fieldnotes. This data representation allows for the tracing of disciplinary content across events with respect to time and the corresponding sequencing of activity showing how and in what ways students engaged with this content.

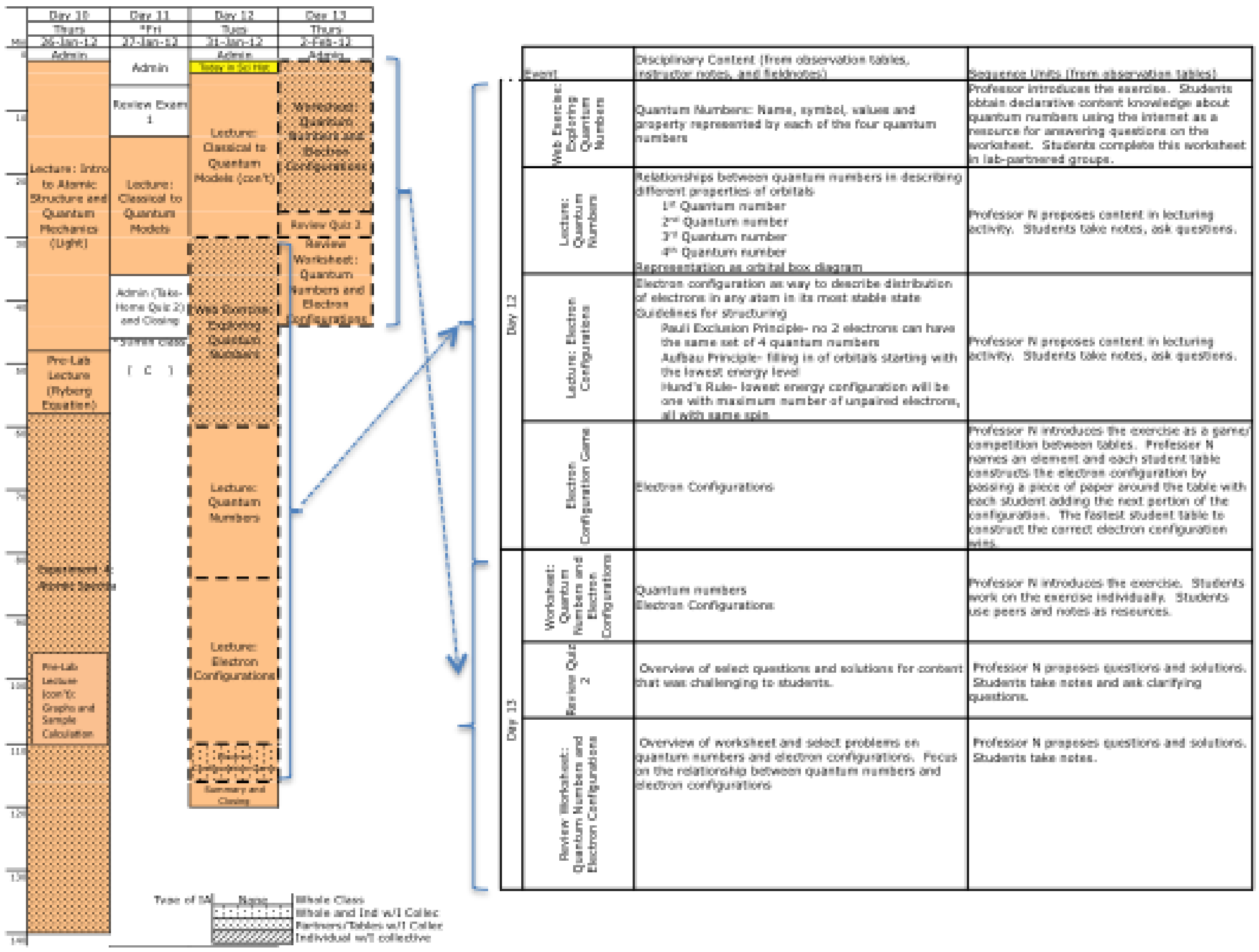
Designing for historical development of quantum theory. Figure 21a highlights the first five content-based events. Analysis of these select events in



Event	Disciplinary Content (from observation tables, instructor notes, and fieldnotes)	Sequence Units (from observation tables)
Lecture: Intro to Atomic Structure and Quantum Mechanics (Light)	Light as electromagnetic radiation Equation: speed of light = wavelength * frequency Parts of the EM spectrum Behavior of light: refraction and diffraction 3 observations that did not fit classical model 1) Blackbody radiation (Planck)- energy is quantized Equation: $E = hv$ 2) Photoelectric effect (Einstein) - need specific frequency to eject electron for an element Equation: $\Phi = hv$ 3) Line spectra for elements Observations resulted in development of model of the atom: Rutherford (1911) and Bohr (1913)	Professor N proposes content in lecturing activity and provides a sample calculation for select Students take notes, ask questions.
Pre-lab Lecture	Atomic Spectra: Ryberg Equation $\frac{1}{\lambda} = 1.097 \times 10^7 m^{-1}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$	Professor N proposes content in lecturing activity and through demonstration of calculation. Making direct connections to experiment. Students take notes, ask questions. Providing guidance for safety procedures and expectations.
Experiment #4 (Atomic Spectra)	Line Spectra (Ryberg Equation) for elements	Students use analytical instruments constructed on Day 9 to obtain data points. Professor N reorients as collective to give guidance on constructing graphs and a sample calculation as a short extension of the pre-lab lecture. Students complete experiment and depart on their own.
Lecture : Classical to Quantum Models	*Highlights of Bohr and Rutherford models* *Link between line spectra and energy* *Energy level diagrams for transitions (Ryberg Equation)* Wave Particle Duality of Light Comptons observation of light behaving as a particle	Professor N proposes content in lecturing activity. Students take notes, ask questions.
Lecture: Classical to Quantum Models (Con't)	deBroglie wavelength Equation: $\lambda = \frac{h}{mu}$ Heisenberg Uncertainty Principle Equation: $\Delta x \bullet m\Delta u \geq \frac{h}{4\pi}$ Schrodinger's Equation- in principle based in psi function for psi² as probability density Orbitals (s, p, d, f)	Professor N proposes content in lecturing activity. Students take notes, ask questions.

Figure 21a. Pullout table showing the historical development of quantum theory and atomic structure presented and flow of activity in engaging with this disciplinary content.

Figure 21a shows that the first three lecture events on Days 10, 11, and 12 (see Figure 19) use a historical context as the primary vehicle to link content. This historical context is also reflected in the patterns of activity from Table 15. The content began with Professor N introducing light on Day 10 within the context of evidence from three key observations (Planck’s blackbody radiation, Einstein’s photoelectric effect, and line spectra for elements). These observations led scientists to think about the structure of the atom in new ways. Consequently, Rutherford and Bohr proposed similar models of the atom, in 1911 and 1913, respectively (Figure 21a, Days 11 and beginning of Day 12). Following this first lecture event on Day 10, students were given an opportunity for learning about one of the key observations, atomic spectra, in the lab cycle of activity, consisting of the pre-lab lecture and experiment. Then on Day 11, Professor N built on Rutherford and Bohr models of atomic structure to introduce Compton’s observation of light behaving as a particle, which is critical in the development of a key principle in quantum theory, the wave-particle duality of light. Constructing this content continued on Day 12 in a summary of principles and equations that form the foundational knowledge of how the science community (currently) thinks about quantum theory at a conceptual level appropriate for undergraduate general chemistry students. These concepts are the deBroglie wavelength, the Heisenberg Uncertainty Principle, and the Schrodinger equation. In this way, these five events on Days 10-12 comprise a cycle of activity in content that shows the historical development of quantum theory which provides the theoretical basis for how the science community models atomic structure.



	Event	Disciplinary Content (from observation tables, instructor notes, and fieldnotes)	Sequence Units (from observation tables)
Day 12	Web Exercise: Exploring Quantum Numbers	Quantum Numbers: Name, symbol, values and property represented by each of the four quantum numbers	Professor introduces the exercise. Students obtain declarative content knowledge about quantum numbers using the internet as a resource for answering questions on the worksheet. Students complete this worksheet in lab-partnered groups.
	Lecture: Quantum Numbers	Relationships between quantum numbers in describing different properties of orbitals 1st Quantum number 2nd Quantum number 3rd Quantum number 4th Quantum number Representation as orbital box diagram	Professor N proposes content in lecturing activity. Students take notes, ask questions.
	Lecture: Electron Configurations	Electron configuration as way to describe distribution of electrons in any atom in its most stable state Guidelines for structuring Pauli Exclusion Principle- no 2 electrons can have the same set of 4 quantum numbers Aufbau Principle- filling in of orbitals starting with the lowest energy level Hund's Rule- lowest energy configuration will be one with maximum number of unpaired electrons, all with same spin	Professor N proposes content in lecturing activity. Students take notes, ask questions.
	Electron Configuration Game	Electron Configurations	Professor N introduces the exercise as a game/competition between tables. Professor N names an element and each student table constructs the electron configuration by passing a piece of paper around the table with each student adding the next portion of the configuration. The fastest student table to construct the correct electron configuration wins.
Day 13	Worksheet: Quantum Numbers and Electron Configurations	Quantum numbers Electron Configurations	Professor N introduces the exercise. Students work on the exercise individually. Students use peers and notes as resources.
	Review Quiz 2	Overview of select questions and solutions for content that was challenging to students.	Professor N proposes questions and solutions. Students take notes and ask clarifying questions.
	Review Worksheet: Quantum Numbers and Electron Configurations	Overview of worksheet and select problems on quantum numbers and electron configurations. Focus on the relationship between quantum numbers and electron configurations	Professor N proposes questions and solutions. Students take notes.

Figure 21b. Pullout table showing flow of disciplinary content for quantum numbers and electron configurations.

Designing for implications of quantum theory for atomic structure (QT/AS) content. Figure 21b shows the remaining events in the quantum theory and atomic structure cycle of activity beginning with the web exercise on Day 12 and ending with the review of worksheet on quantum numbers and electron configurations. Key designing implications are made visible by contrasting the flow of content between events in Figure 21a and 21b. Both pullout tables in Figure 21a and 21b show disciplinary content and sequence units by event and by day. Unlike the historical development of content in Figure 21a, this content, quantum numbers and electron configurations, developed from implications of the quantum model of the atom. It began on Day 12 when students did a web exercise on exploring quantum numbers followed by a lecture event on quantum numbers. These two events constituted a lecture cycle of activity about quantum numbers, with a modified flow of activity from a lecture cycle of activity in the 1st exam cycle of activity (See Figure 15), which will be compared in more detail in the next section. Within a lecturing activity, the instructor then transitioned from quantum numbers to electron configuration content. This initiated the next lecture cycle of activity consisting of a lecture event on electron configurations and a competitive electron configuration game between table groups.

In this second half of the quantum theory and atomic structure cycle of activity (Figure 21b), the participants used the principles of quantum theory as the basis to construct the symbolic representations for atomic orbitals (quantum numbers) and the distribution of electrons within an atom (electron configurations).

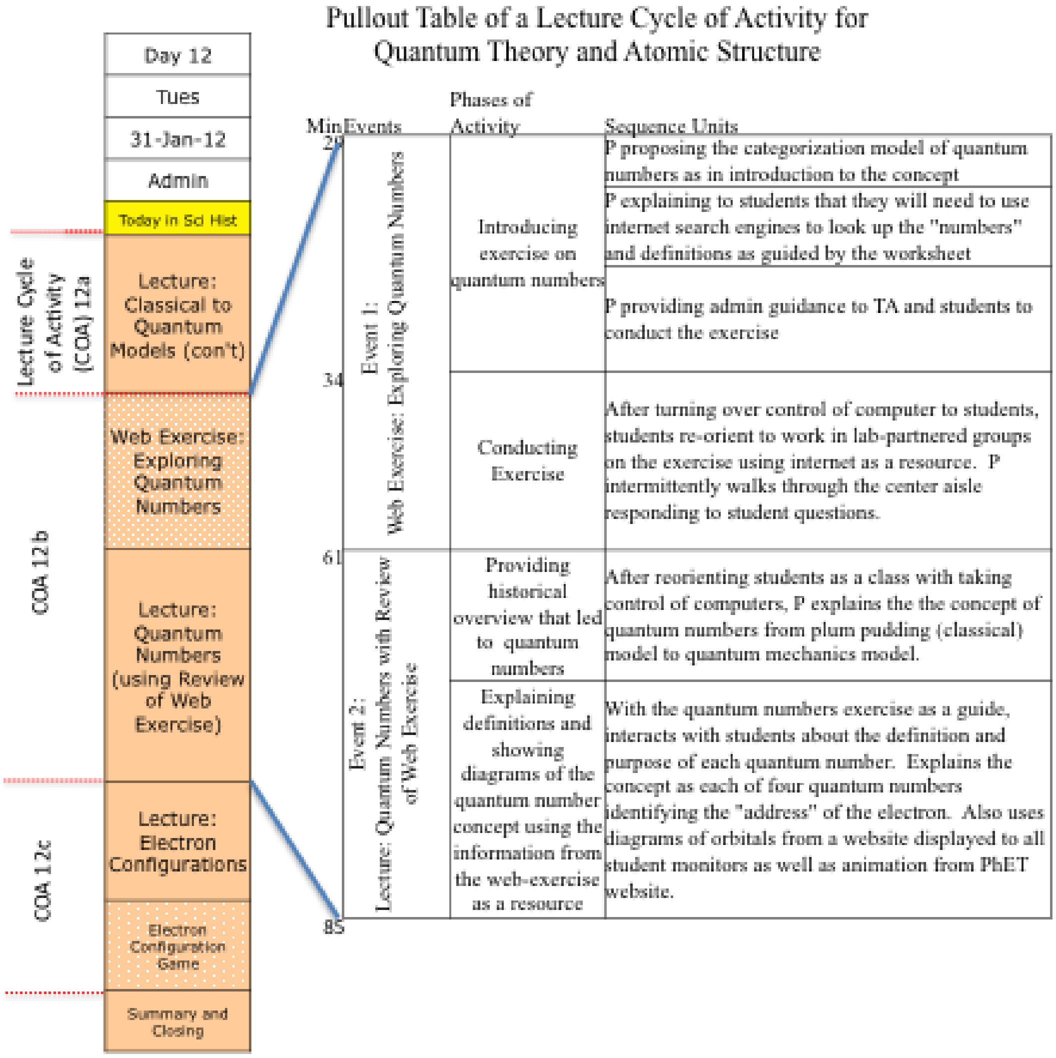
Specifically, quantum numbers is a symbolic system that represents electron "location" (probabilistic location linked to a relative energy level). Likewise, electron configurations is another symbolic system that builds on the quantum number symbology with emphasis on spatial orientation. Although there are references to historical figures such as Wolfgang Pauli and Friedrich Hund, this content gives preference to showing how quantum numbers and electron configurations are conceptually in a traditional way (i.e., structured by the discipline (Posner, 2004)) rather than from a historical perspective.

Within events such as the web exercise on quantum numbers as well as lectures on quantum numbers and electron configuration, Professor N and students constructed implications and applications of the quantum model of the atom within the culturally accepted ways of structuring the content. In this way, the story of this quantum theory and atomic structure cycle of activity in this class is one of the development of present day quantum theory (Figure 21a) and its implications for how the chemistry community models atomic structure (Figure 21b) at a level appropriate for undergraduate general chemistry students.

Designing for Lecture Cycles of Activity. In the prior section, constructing the "story" of quantum mechanics and atomic structure was shown as two different bases by which content was proposed to students in this quantum theory and atomic structure cycle of activity: historical for development of the theory and then traditional for applying this theory by constructing a common language (symbology) to conceptualize and talk about atomic structure. This section looks at the same events from another perspective still based in structuring of events. Here, I take a more directed look at select lecture cycles of activity on a lecture day in the quantum theory and atomic structure cycle of activity in order to make visible how and in what ways that what counts as a lecture cycle of activity is expanded, namely with the inclusion of a web exercise event on Day 12. This adds to the possible ways in which content is proposed within lecture cycles of activity.

Figure 22 shows each of the three lecture cycles of activity on Day 12. I analyzed activity and events within the first two lecture cycles of activity on this lecture day to make visible these additional ways of proposing content to students in this course. How and in what ways this course functions was determined largely by the actions of participants in the constructing of their world. Fundamental to this process also included how and in what ways actors contextualize the structure of their world through how they talk about an event or process. For the case of Day 12, Table 19 shows how Professor N planned for designing of instruction as she explained her general schedule for the day to a TA prior to the beginning of class on Day 12.

Table 19 shows that “finish[ing] up Chapter 7” (Line 3) consisted of “going back over the Bohr model a little bit, do[ing] Heisenberg [and] Schrodinger” (Lines 5-8). This is the content proposed in Lecture Cycle of Activity 12a. Then she explained that “they’ll [students] do quantum numbers… then we’ll go over quantum numbers [and] orbitals” (Lines 9-12). This is the sequence of events in Lecture Cycle of Activity 12b. She continued to explain that “then we’ll start electron configurations probably if they seem to be holding up" (Lines 13-14). Electron configurations is the disciplinary content covered in Lecture Cycle of Activity 12c.



Pullout Table of a Lecture Cycle of Activity for Quantum Theory and Atomic Structure

Min	Events	Phases of Activity	Sequence Units
29	Event 1: Web Exercise: Exploring Quantum Numbers	Introducing exercise on quantum numbers	P proposing the categorization model of quantum numbers as in introduction to the concept
			P explaining to students that they will need to use internet search engines to look up the "numbers" and definitions as guided by the worksheet
			P providing admin guidance to TA and students to conduct the exercise
34		Conducting Exercise	After turning over control of computer to students, students re-orient to work in lab-partnered groups on the exercise using internet as a resource. P intermittently walks through the center aisle responding to student questions.
61	Event 2: Lecture: Quantum Numbers with Review of Web Exercise	Providing historical overview that led to quantum numbers	After reorienting students as a class with taking control of computers, P explains the the concept of quantum numbers from plum pudding (classical) model to quantum mechanics model.
		Explaining definitions and showing diagrams of the quantum number concept using the information from the web-exercise as a resource	With the quantum numbers exercise as a guide, interacts with students about the definition and purpose of each quantum number. Explains the concept as each of four quantum numbers identifying the "address" of the electron. Also uses diagrams of orbitals from a website displayed to all student monitors as well as animation from PhET website.

Figure 22. Lecture cycles of activity on Day 12 highlighting a pullout table for Lecture Cycle of Activity 12b.

Table 19

Transcript Selection of Professor N Explaining her Plan for the Day to a TA Prior to Class on Day 12

Line	Professor N
1	
2	um
3	finish up chapter 7
4	so
5	go back over the Bohr model a little bit
6	do Heisenberg
7	uh
8	Schrodinger
9	they'll do quantum numbers
10	um
11	then we'll go over quantum numbers
12	orbitals
13	and then we'll start electron configurations probably
14	if they seem to be holding up

Each of these cycles of activity contributes in a different way to the variability in what can happen within a lecture cycle of activity. For example, for the first time in Lecture Cycle of Activity 12c, a lecture cycle of activity began with a lecture event on electron configurations followed by a competitive game between tables. Analysis of Lecture Cycles of Activity 12a and 12b will be addressed in detail in the following sections.

As mentioned previously, in Lecture Cycle of Activity 12a consisting of one 25-minute event, Professor N proposed to students how the quantum model of atomic structure has been constructed by the scientific community from a historical perspective. This content began on Day 10 with a lecture event on light and ended with the significant developments in the modeling of atomic structure contributed by the deBroglie wavelength, Heisenberg Uncertainty Principle and the Schrodinger equation on Day 12 (see Figure 21b). The content proposed in lecture events on Day 10, 11 and Lecture Cycle of Activity 12a on Day 12 all came from the same chapter in the textbook, *Chapter 7- Nature of Atoms: Spectroscopy, Electrons and Quantum Number*, in accordance with the course syllabus. The sequence units from Lecture Cycle of Activity 12a (see Figure 21a) show that significant principles included mathematical equations which were applied in non-workbook problems proposed and demonstrated by the instructor. In this way, a lecture cycle of activity does not necessarily require student engagement within group interactional spaces in, say, workbook problems, like was shown in the thermodynamics cycle of activity (see Figure 12). It is also possible that the instructor's concern for catching up to her planned content schedule prompted her to forego an event that accessed group interactional spaces in order to use more time for proposing content in the designing of instruction for this lecture day.

Figure 22 shows Lecture Cycle of Activity 12b represented as a pullout table showing events, phases of activity, and sequence units. This lecture cycle of activity occurred between minutes 29 and 85 from the actual class start time. It consisted of two events: a web exercise on exploring quantum numbers and a lecture on quantum numbers.

The first event in Lecture Cycle of Activity 12b was a web exercise on exploring quantum numbers. This event consisted of two phases of activity. In the first phase of activity, Professor N introduced the exercise with an overview of the purpose of quantum numbers symbology but she did not provide the declarative knowledge about how the system works. In the second phase of activity, students worked in their lab partnered groups to answer questions from a worksheet (see Appendix H) that provide the general framework for the organizational system of quantum numbers with the internet as the primary resource.

The following conversation between Professor N and a TA prior to the start of class on Day 12 provides information that suggests that this content may be better presented in a form other than a lecture event:

Table 20

Transcript Selection of Conversation between TA and Professor Prior to the Start of Class on Day 12

Line	Professor N	TA
1		[Holding quantum number worksheet]
2		[inaudible] easy-ish
3	yeah they're just	
4	they are kinda dry	
5	to teach	yeah
6		'cause it's just more like
7	yeah	memorizing what they are
8	yeah	and then you're fine
9		whenever it was on a test
10		it was like YES
11	[laughing]	

This short conversation between professor and TA shows that the meaning of the content being "kinda dry to teach" (Table 20, Lines 4-5) as proposed by the professor translates in the student perspective/TA as being easily memorized and reproduced for an exam (Table 20, Lines 6-10) as discussed by the TA within her own experience as having been a student learning about quantum numbers. The professor's verbal (Table 20, Lines 7-8) and non-verbal responses (Table 20, Line 11) signaled that she was in agreement with the TA. The web-based exercise may also have been an effort to break up the longer lecture events on this lecture day to maintain student engagement with the material, especially the content that may be more "dry". In this way, this web exercise served the same purpose as the workbook problems- to provide the conditions where students actively engaged with the content. However, in this case, students found the information for themselves via the internet.

Unlike previous lecture cycles of activity in the 1st Exam Cycle of Activity, the symbology and meanings for quantum numbers was not explained to students as new information in a lecture event prior to students doing the quantum numbers exercise. Rather, students were given the responsibility to find out the basic categorical framework for quantum numbers within table and lab-partner interactional spaces. This transfer of responsibility is made visible in Lines 9 and 11 of Table 20 when Professor N emphasized that "they'll do quantum numbers" (Line 9) where "they" refers to students. Professor N then signaled that she planned to reorient students collectively in a lecture event on quantum numbers when she said "then we'll go over quantum numbers" (Table 20, Line 11).

The second event in Lecture Cycle of Activity 12b was a lecture on quantum numbers. The web exercise event was followed by a lecture event on quantum numbers. As shown in Figures 21a and 21b, Professor N drew on the information that students acquired from the web exercise as a resource and framework so that students participated in constructing and reformulating the quantum number organizational system. This content included linking quantum numbers to orbitals which is the organizational unit for atomic structure within a quantum model.

The web exercise on exploring quantum numbers followed by the lecture event on quantum numbers constituted a type of lecture cycle of activity that is in an interesting contrast to lecture cycles of activity seen in the 1st exam cycle of activity. Visual analysis of pullout tables for Figure 15 and Figure 20 show that each cycle of activity has one lecture event and one workbook or exercise event where students accessed table and lab-partner interactional spaces to engage with content. However, the order of these events are switched. In the 1st Exam Cycle of Activity, the professor driven lecture event preceded the student driven workbook exercise. In Lecture Cycle of Activity 12b, the web exercise preceded the lecture event. This sequence extends the variability for what counts as a lecture cycle of activity showing the options available to instructor and students for constructing opportunities for learning in this class. Moreover, the sequencing of the student driven exercise prior to the instructor driven lecture in Figure 20 shifted primary responsibility for constructing an opportunity for learning new information from instructor to student.

Summary of Findings for Chapter IV

In this chapter, I described how and in what ways participants structured opportunities for learning disciplinary content through activity, events, and various levels of cycles of activity in this course. This analysis suggests that the flexibility in the designing of instruction can be attributed to the accessibility of table and lab-partner group interactional spaces in both lecture and lab cycles of activity. In comparing activity, events, and various levels of cycles of activity, it is clear that how content is proposed to students differs between the two exam cycles of activity, generally, and between thermodynamics and quantum theory and atomic structure, specifically. This analysis suggests that differences in conceptual demands (calculations-based in thermodynamics and symbolic-based in quantum theory and atomic structure) influenced the designing of instruction. Specifically for the General Chemistry level of coverage within these disciplinary content areas, responsibility for obtaining initial declarative knowledge (of some topics in quantum numbers and periodic properties) was transferred from instructor to students.

With respect to foregrounding the analysis in the next chapter on problem solving, this chapter makes visible how Professor N used example problems, workbook problems, and problems in experiments as the primary means of proposing content and affording students opportunities to use the content. In the chemical education field, “doing chemistry” has been identified as synonymous with problem solving in chemistry (Bodner & Herron, 2002). So this analytical description of how this course functions in the day-to-day and moment-to-moment events and activity also makes visible the general structuring of problem solving activity.

In the next chapter, I will explore how these differences manifest in activity at the analytical level of discourse within instructor-student and student-student interactions as participants construct what counts as general chemistry disciplinary practices for “doing chemistry”.

Chapter V: Data Analysis and Findings- Problem Solving

Overview

In Chapter IV, I provided an analytical description of how this undergraduate General Chemistry for Engineering Majors course functioned with respect to the structuring elements (events and activity) for the designing of instruction. Now, I shift the analytical perspective from examining the structuring of events and activity linked by disciplinary content to exploring how and in what ways a critical course practice, that was signaled as socially significant by the instructor, was proposed and taken up by actors in this class.

In approaching the study of this studio learning environment, a reoccurring theme was made visible during the prior analysis of how and in what ways the course functioned. This reoccurring activity was referred to by the professor in the class as “problem solving”. Within the literature review in this study, I discussed how problem solving has been defined and studied generally and within the chemistry education discipline specifically. However, as discussed previously in Chapter IV through an ethnographic perspective (Green et al., 2003), the meaning of any activity or event is actively co-constructed and negotiated by members of, in this case, this class as a sociocultural group in and through interactions with each other and cultural artifacts. As such, “problem solving” and "applying concepts" are socially constructed. The meaning of “problem solving” (or any activity or event) is continuously being proposed, negotiated, and affirmed within the sociocultural group in which the activity (or event) transpires. Simply, what counts as “problem solving” or "applying concepts" in this course can not be assumed or predicted. Rather, these meanings must be made visible within the ways and means that actors orient to and engage in problem solving activity in the everyday life of their class. The purpose of this chapter is to address how problem solving practices are proposed, negotiated and taken up in this course by tracing the process of class participants negotiating what they must know, think, and do in order to become an accepted member of this cultural group with respect to doing “problem solving” with special attention to the practice of “applying a concept”.

Records and data. This section draws on records and data constructed from the 2012 video and documentation archive from the same first six weeks of the course that was analyzed in Chapter IV. As a result, I draw on the same structuring elements that I developed in Chapter IV such as “lab”, “lecturing”, “lecture”, “cycle of activity”, and others as resources for this analysis.

Anchoring the analysis. As mentioned in Chapter II, the topic of applying concepts was signaled by the instructor as a socially significant practice in this course when she commented in an email to the researcher about a specific problem on the exam, Problem 20 of Exam 2:

> I thought they would miss it [Problem 20 on Exam 2] because it was different, it was a new context for the E=hc/lambda equation, something TOTALLY different from what we’d used that equation for. And I think they missed it exactly for that reason- They might understand the concepts in the context that

> I give it to them in, but they have a horrible time applying concepts to new different contexts. (Email correspondence, 15 Feb 2012)

In this email comment, the instructor extended the significance of students missing this one question to a more general statement of “they have a horrible time applying concepts to new different contexts”. By Professor N's statement, this issue of students not being able to extend understanding of a concept to new contexts is not a reflection of just this one content area or just one student. By this statement, being able to apply concepts in new contexts is a socially and academically significant practice. However, according to this instructor, this practice of applying concepts is not being taken up by students. The instructor's statement calls for a need to examine the opportunities students have for applying concepts and understand how and in what ways participants co-construct problem solving practices.

This situation served as the frameclash (Mehan, 1979) for me, the ethnographer/researcher, and initiated the research question that guided the logic of inquiry into problem solving practices, specifically applying concepts: How and in what ways do participants construct opportunities for learning how to use or apply concepts in this course?

Problem solving as a "text". In order to examine how and in what ways students were afforded these opportunities, I approached the analysis as a trace of a "text" (Bloome et al., 2010) for problem solving. Based on an initial assumption from my class observations that "applying a concept" was a fundamental practice that constituted "problem solving", I approached the analysis as a trace of "problem solving" within which I could locate "applying a concept". Therefore, constructing problem solving as a text means that what counts as problem solving is co-constructed over time and made available to actors as a resource in (future) problem solving activity. In this way, what counts as problem solving and applying a concept was continuously modified, reinforced, suspended, and evolving over the 10-week course.

This text for doing problem solving first came into being at the beginning of the course in how the instructor positioned problem solving through course documents and introductory comments on the first day of class. Then this planned framework for problem solving became a resource for participants as they proposed and negotiated how to engage in problem solving over time. Instructor and students co-constructed the disciplinary content in class events and activity through proposing and using the select disciplinary content area required for students to do a specific problem on the exam, Problem 20 of Exam 2. Problem 20 of Exam 2 was the specific problem that students found challenging on the exam according to Professor N.

Research Questions

The logic of inquiry and methodology for this chapter is shown in Figure 8c and Table 1, respectively, in Chapter III. The logic of inquiry for this data analysis section (see Figure 8c) is partitioned in three major questions (Research Questions 3-5). The research questions are:

Research Question 3. In what ways did the instructor frame (or position) problem solving in course documents and introductory comments in the course?

Research Question 4. In what ways was select disciplinary content proposed and negotiated by participants over time in collective activity?

Research Question 5. In what ways did students construct opportunities for learning how to use or apply concepts for the selected disciplinary content (in Question 4) within lab-partnered group and table interactional spaces?

The first major question, Question 3, addresses how problem solving is positioned by the instructor from what she makes available to students through course documentation and her introductory comments about problem solving at the beginning of the course (or as needed thereafter). The nature of the data in this major section is that it is void of specific disciplinary content. In effect, these make visible the instructor's expectations for how students should engage with any disciplinary content in problem solving activity.

The second major question, Question 4, explores problem solving as a process of engaging with disciplinary content within the interactional spaces, events, activities or cycles of activity identified in Question 3. Specifically, Question 4 backward traces the construction of disciplinary knowledge over time and interactional spaces where problem solving practices for specified content for Problem 20 of Exam 2 were proposed then used as a resource by students on the exam. In this way, I made visible all the material resources available and required for students to complete a select question on the exam.

Then in the third major question, Question 5, I adjusted the analytical lens from the collective level to the table and lab-partnered group level of analysis. Here, I examined what was happening (what and who students were orienting to, for what purposes, and with what outcomes) within the table and lab-partnered group interactional spaces, a unique aspect of the studio learning environment, within a select event from the trace in Question 4. This is an exploratory analysis of how an in what ways these interactional spaces contributed to opportunities for learning problem solving practices in this course.

Data and Findings by Research Question

Research Question 3. In what ways did the instructor frame (or position) problem solving in course documents and introductory comments in the course?

The focus of this research question makes visible the salient elements within the course documentation and instructor's introductory comments that, together, show how the instructor framed problem solving in this course as opposed to *doing* problem solving as discipline-based collective activity. The *doing* of problem solving will be addressed in Research Questions 4 and 5.

In order to begin reconstructing a text for problem solving practices in this course, in this section, I (re)present how and in what ways the instructor proposed how students should engage in problem solving from available course documentation and the instructor’s introductory guidance about problem solving in the first few days of class. I entered the records from the perspective of the student whose first interaction as a member of the class occurred before they entered the general chemistry studio on the first day. The onset of group began when students received a welcome email from Professor N identifying the student as a member of her class.

According to the instructor, she typically provided access to the course online documentation in the email prior to the first class day. However, for this specific group of students, there is no evidence in the records archive or by instructor's recollection (Neff, Personal communication, March 18, 2013) whether this occurred or not. Notwithstanding this point, the course documentation was available to students no later than the first day of a class. Therefore, under these conditions, the choice of beginning the analysis with the course documentation or instructor guidance was arbitrary. However, I elected to begin the analysis of the course documentation because it was fully available no later than Day 1 whereas the instructor's guidance was not completed until Day 3.

From two course documents that address problem solving explicitly, Table 21 and Figure 23 were constructed to make visible how the instructor positioned problem solving within the framework of skills that students were expected to develop in this course (Table 21) and the recommended habits of engaging with content for achieving success in the course (Figure 23). The documents are the central features (the hubs) in these representations. Where Table 21 and Figure 23 were constructed as data from selected course documents, Figure 24 shows problem solving as the central hub with elements and relationships from both the online documentation and the instructor’s verbal guidance about problem solving in collective interactional spaces. Recall that collective interactional spaces are defined as the space where all participants are orienting to and engaging in the same designated activity.

In much the same way that actors position themselves and others in negotiated interactions, within this conceptual framework, actors are also positioning and being positioned by written texts (Bazerman & Prior, 2004). Professor N initiated this conversation with her students through course documentation that she made available to all students on or before the first day of class. The course web page (Appendix J1) features the "dynamic course syllabus" which Professor N updated continuously through the quarter with links and schedules changes as needed. Six web based documents were available to students as links from the course web page: syllabus and course information, instructor's schedule, laboratory guidelines and procedures, grading and honesty policy, graphing tips, and guide for Achieving Success in Chem124. The salient documents for this analysis, syllabus and course information and Guide for Achieving Success in Chem 124 are available as Appendices J2 and J3 respectively. Entry to the course documentation in this study proceeded as a student might enter the material, beginning with the 2-page syllabus and course information document. Of the available online resources, two provided explicit information regarding the theme of "problem solving": the course information document and "Achieving Success in Chem 124". In this section, each of these will be analyzed separately.

Analysis of syllabus and course information document. The course information document provided general course information (see Appendix J2) and provided the first introduction to how the instructor positioned problem solving in this course.

Problem solving was addressed in two paragraphs in this document: the introductory paragraph and the homework section.

Introductory paragraph. The introductory paragraph consists of six sentences that provide the most general overview of the course. In order to analyze how problem solving is positioned in the introductory paragraph, each of the six sentences is shown and analyzed as a separate unit (see Table 21) for content and rhetorical elements that provide expectations of students and position salient activity, such as problem solving. Unlike the representations of verbal discourse in prior analyses as message units, written text provides cues such as punctuation, capitalization and font type (such as italics) signaling intentioned units. These structures are maintained in Table 21. There are several important implications for students that position the course as designed for engineers (Sentence 1) with expectations what students need to know (Sentence 3) and what skills they should develop (Sentence 4). By italicizing sentences 5 and 6, Professor N signaled that these are important ideas for students to consider. These position chemistry in relation to engineering and, within this conceptual framework, positions the instructor as cultural guide to the ways of knowing, thinking and doing chemistry.

Direct references to "problem solving" (Sentence 4) and "problem" (Sentence 6) are shown in bold type in Table 21. In Sentence 4, "algorithmic problem solving" is identified as a skill that Professor N hoped (Sentence 6, Table 21) that students will develop in this course. However, the meaning of “algorithmic” was not defined. In Sentence 6, Professor N positioned the field of chemistry with respect to the field of

Table 21

Rhetorical and Content Analysis of Introductory Paragraph from Course Information Document

Sentence Number	Introductory paragraph from course information online document	Implications for students within conceptual framework (especially in framing of problem solving practice or processes)
1	Chemistry 124 is a general chemistry course designed for students in engineering.	This General Chemistry course for student-engineers is different than for student-chemists/scientists. Implies that engineering students need to know chemistry in a different way than scientists do. Implies engineering as "other" in chemistry discipline.
2	This is a fast-paced, rigorous course that requires a year of high school chemistry as a prerequisite.	Students are expected to draw on the practices and content knowledge from high school chemistry as a resource for this course. Students need to plan for keeping up with the fast pace of the course.
3	By the end of this quarter you should be able to master and **apply** fundamental concepts of thermochemistry, quantum theory & atomic structure, periodic properties, chemical bonding, solid state chemistry and materials, and basic organic chemistry.	A critical element of this course is that students be able to **apply** concepts in these six major content areas that constitute General Chemistry for engineering majors. The meaning of "applying concepts" is not made explicit but potentially related to problem solving. Because this is a chemistry course designed for engineers (Sentence 1), this implies that disciplinary content could have special relevance for engineering.
4	The skills I hope you develop this term include critical thinking, algorithmic **problem solving**, experiment design and analysis, writing, and information acquisition using the computer.	Shows that algorithmic problem solving is a type of problem solving although what "algorithmic" means is unknown. Within the conceptual framework, the meaning of "algorithmic problems solving" may be constructed in actions and interactions of course participants as they engage in problem solving activity over time.
5	*I believe that chemistry is the language of the natural world and, as such, through understanding chemistry you will be able to better understand the world around you.*	Professor N signals the importance of this sentence with italics. Positions Professor N as a gatekeeper of knowledge that will be accessible to students once they understand the language of chemistry. Professor N positions herself as a cultural insider into this "language". "Language" refers to the ways of knowing, thinking, and doing chemistry. Professor N is appealing to student as scholar identity as a motivator to learn and understand chemistry.
6	*More specifically, I hope you will be able to see how chemistry is involved in so many concepts **applicable** to engineering **problems**.*	Professor signals the importance of this statement with italics. This clarifies Sentence #5 and positions chemistry as important to engineering. Positions chemistry disciplinary concepts as a means of understanding the natural world which can be applied to engineering problems. Implies that understanding chemistry concepts will help students understand engineering problems.

engineering to appeal to the engineering students as to why they need to know the information in this course. She argued that the chemistry content (concepts) is an important element that can be *applied to* (and presumably help solve) engineering problems.

Homework section. The course information document (see Appendix J2) also includes a section that lists major topics under the heading "course organization". One of these, the homework section, makes direct reference to solving problems. Analysis of this section is shown in Table 22. Analysis of the homework section from the course information document shows significant implications for students with regards to doing problems. In Sentence 1, Professor N provided a stark warning that "you [students] cannot succeed in this course without doing problems" in the

Table 22

Rhetorical and Content Analysis of Homework Section from Course Information Document

Sentence Number	Homework section from course information online document	Implications for students within conceptual framework (especially in framing of problem solving practice or processes)
1	Homework is not typically collected in this class, yet you cannot succeed in this course without doing problems.	Homework consists of doing problems as self regulated by the student outside of class time. Professor N signals that doing problems outside of class time is critical to student success in this course.
2	See section on Course Information and Expectations on my website and read the online page on Achieving Success in Chem 124.	Intertextual tie to other texts that provide more information about the meaning of "doing problems". The importance of doing problems from Sentence 1 may motivate students to follow the link into the other documents.

context of doing problems outside of the formal class time. The implication for students is that doing problems is a critical part of meeting performance expectations for this course such that there is some skill or knowledge to be gained from doing problems outside of the formal class period that will positively influence course performance. As guided by this document (Sentence 2, Table 22), the next step is to analyze the Achieving Success in Chem 124 document.

Analysis of the Achieving Success (AS) in Chem 124 document. The Achieving Success in Chem 124 document (see Appendix J3) was accessible through a link on Professor N’s course webpage. This document has three major sections: recommended work ethic of students, course goals, and guidelines for success for Chem 124. The first major section lists seven elements of a work ethic that Professor N recommended. One of these is “keeping up with text readings and problem-solving on a daily basis rather than cramming before exams or quizzes” (Achieving Success in Chem 124). The second major section lists two course goals found verbatim in the course information paragraph (Table 21, Sentences 3 and 4), with the exception that in this document the words “fundamental concepts” (Table 21, Sentence 3) and “skills” (Table 21, Sentence 4) are annotated in bold type. These first and second sections in this document provide very general guidelines or recommendations from Professor N about what students need to do and need to know to be successful in this course. The third section explains what to “do”, especially with respect to problem solving and will be analyzed in detail for the remainder of this section. Of all the documentation, this artifact provides the most detailed guidance for problem solving within the third of the three sections.

Taxonomic analysis of Achieving Success in Chem 124. A visual representation of how the instructor framed what students need to do to succeed in this course is shown in a taxonomic map (Figure 23) constructed from the elements and relationships from the third section of the Achieving Success in Chem 124 document (see Appendix J3).

Figure 23 shows one way of representing the information in this documentation record. A dotted horizontal line visually divides the elements and relationships into two major areas by location (inside or outside of the formal class time) to reflect this major division in the document. The top half of the figure shows recommendations for how and in what ways students should engage with content while in the formal class period. The bottom half shows how the instructor frames how students should engage with content outside of the class. Capitalized words from the document signifying emphasis are also capitalized in the figure.

Expanding out from the central hub of “Achieving Success in Chem124”, key elements of guidance from the original document signal the instructor's expectations of students. Key elements are linked by relationships. Comments from the instructor that explain her reasoning for making these recommendations are labeled as “metadiscourse” and quote the original document. Elements directly relating to problem solving practices are shaded.

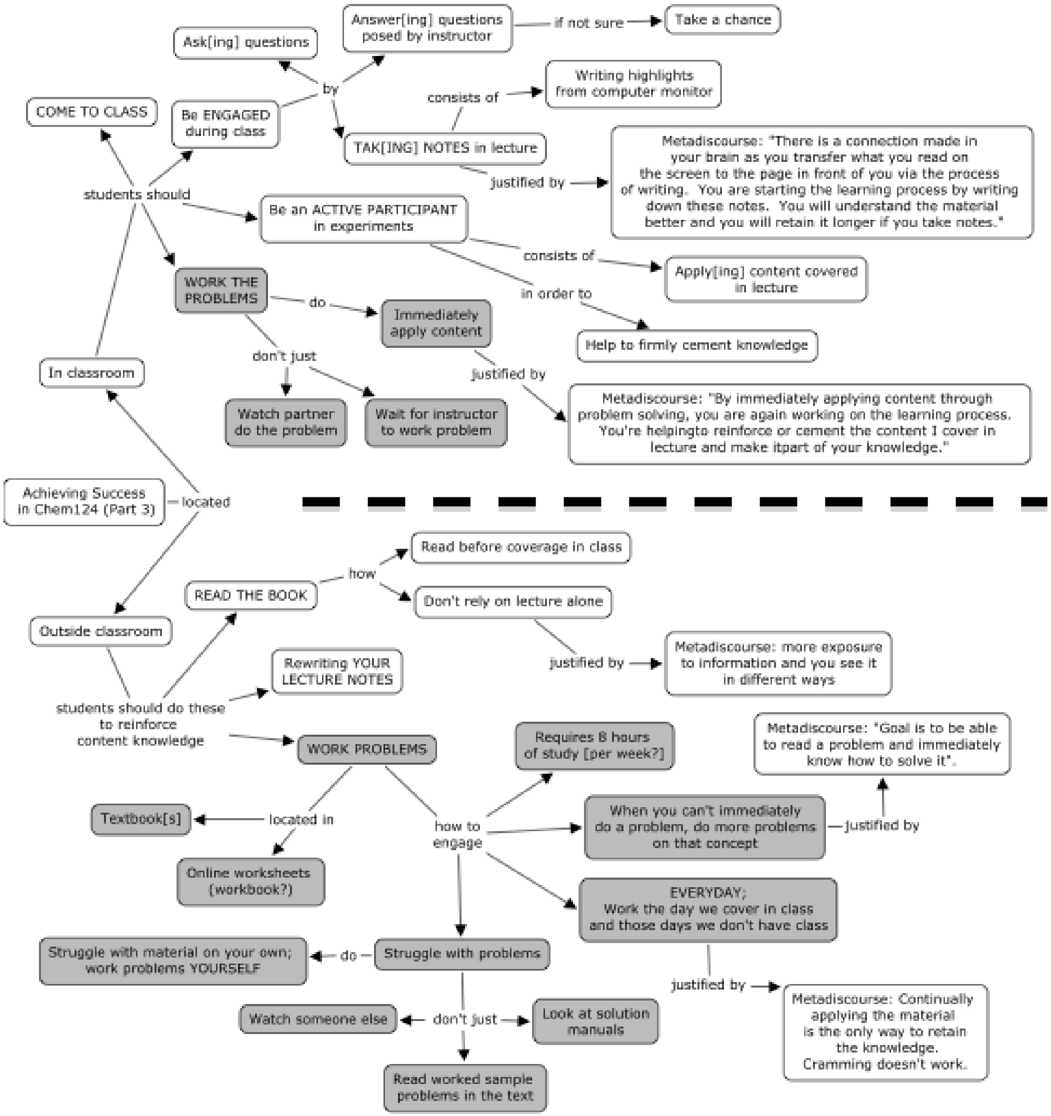


Figure 23. Taxonomic analysis of the online resource 'Achieving Success in Chem 124' (General Chemistry for Engineering Majors). Yellow background identifies concepts related to 'problem solving'. Dashed line separates guidance for in the classroom (above) and outside the classroom (below).

One of the first things noticeable in this visual representation is that problem solving guidance comprised nearly half of the guidance from the instructor with respect to achieving success in this course. This again signals problem solving as an academically and socially significant element in this course. Also, there are many more guidance elements for problem solving outside of class (below the line) compared to inside of class (above the line). This implies that doing well in this course requires significant effort outside of class; students have a responsibility for doing problem solving on their own. This process of doing problems outside of class is characterized as a "struggle" in terms of what students should do (do problems yourself) and not just do (watch someone else, work sample problems in class, and look at solution manuals). In this way, "class" extends beyond the formal space (physical and in time) of the classroom to include the opportunities for learning that students afford themselves as they work problems outside of class.

In class, working the problems is one of four main actions that Professor N recommended her students do, but it is not the most significant. By virtue of the number of immediate connections and follow-on connections consisting of specific guidance, "being engaged in class" in the various ways shown in the figure is the most significant action within the formal class that can help students be successful in this course. This theme of engagement in class is also relevant to problem solving. By explaining that problem solving is not just watching your partner do the problem and not just waiting for the instructor to do the problem, Professor N urged students to engage with problems themselves within the opportunities afforded within the class period.

Content and Rhetorical Analysis of Achieving Success in Chem 124 Document. The portion of the Achieving Success in Chem 124 document (see Appendix J3) was analyzed further for its content and rhetorical elements in framing problem solving, especially with respect to applying concepts. As annotated in Table 23, Section A shows the “What to do INSIDE of class” paragraph and Section B shows “What to do OUTSIDE of class” paragraph.

Analysis of Section A for what to do inside of a class highlights that students should "work the problems" in class (Section A1, Table 23). This implied that students are provided opportunities to work problems in class, from what I have shown thus far, in workbook problem solving sessions. However, it is not clear what "work the problems" means. Although students bring their presuppositions as to what "work" means from everyday life and prior schooling experience, at this point in the course, "work" was proposed by the instructor as an insider term. What it means to "work the problem" would be constructed by instructor and students as they engaged in (future) problem solving activity. In addition, the term "applying" (Table 23, Section A3a) was used to as the cover term for students using a concept proposed by the instructor in class in the context of Sections A1 and A2 that preceded it. Furthermore, from the phrase "applying concepts through problem solving" it is clear that students will be required to apply concepts when they do problem solving

Table 23

Discourse Analysis of Select Sections of the Achieving Success in Chem 124 Document*

Section		Text from Document	Implications for students within conceptual framework (especially in framing of problem solving practices or processes)
A: Within "What to do INSIDE of class" paragraph			
A	1	WORK THE PROBLEMS we take the time to do together in class.	Capitalized phrase "WORK THE PROBLEMS" signals the importance of doing this activity. Specifies that these are in-class problems.
A	2	Don't just sit there and wait for me to go over the problem, don't just watch your partner do the problem.	Clarification of meaning of "working the problems" in terms of what students should not be doing. Use of comma to link two sentences signals a strong tie between the two. Repeated use of "don't just" is rhetorical device to show emphasis of what not to do. Implies that when students are "work[ing] the problems", they have time to do this work alone or with their lab partner.
A	3a	By immediately applying content through problem solving,	This phrase is in reference to Sentence 1 where problem solving is equivalent to "Work[ing] the problems". Also, problem solving is, in part, constituted by applying content.
A	3b	you are again working on the learning process,	With Section A3a, learning is a process of applying content through problem solving.
A	3c	you're helping to reinforce or cement the content I cover in lecture and make it part of your knowledge.	Like in Section A2, Section A3 is constituted by two true sentences tied in meaning. Here, Sections A2a and 3b are restated in Phrase 3c. In order to learn the material, the content needs to be applied in problem solving practice by working problems soon after Professor N proposes disciplinary content in a lecture event.
B: Within "What to do OUTSIDE of class" paragraph			
B	1	Next, WORK PROBLEMS.	Capitalized phrase "WORK PROBLEMS" signals the importance of working problems which is repeated from Sentence A1. Generalizing to "problems" rather than "the problems" signals that the choice of problems is at student discretion.

B	2	Work the problems I suggest in the text, work on the worksheets I post online, and really struggle with these problems.	Suggested problems in the text (or texts for Silberberg and Tro textbooks) are shown in the dynamic syllabus online. Unclear if instructor is referring to the workbook as worksheets that is posted online. The reference to “struggle with the problems” shows that Professor N expects that students will not immediately be able to know the path to a solution. This also implies that the struggle is to some extent an individual endeavor and that struggling with doing problems is expected for students in this class.
B	3	If you can’t immediately do a problem, but need to consult your book or the lecture notes, then you need to do more problems that cover that concept.	What counts as knowing a concept is being able to identify the appropriate concept applicable to solving the problem and knowing how to solve the problem immediately. With the prior sentence, the implication is that students should continue to work problems until they no longer struggle with them.
B	4	Your goal is to be able to read a problem and immediately know how to solve it.	Explicitly stating the goal which was stated implicitly in Sentences B2 and B3.
B	5	How and when you work problems is nearly as important as working the problems.	Introduction to how and when students should work the problems.
B	6	You should work on chemistry problems EVERYDAY.	Capitalization of EVERDAY to show emphasis. Problem solving processes in this class must be exercised daily.
B	7	You should be spending about 8 hours outside of class working on chemistry.	Quantification for time that should be dedicated to chemistry outside of class time. Assuming this is 8 hours a week.
B	8	Don’t just cram before an exam or quiz, but work problems the day we cover that concept in class, and then work problems on the days we don’t have class.	Another reference to what not to do (don’t just cram) reinforces what TO do in the next phrase (work problems the day we cover that concept in class). Rhetorical technique of placing what not to do followed by the accepted alternative is an effort by the instructor to influence students towards what she considered to be good study habits.
B	9	Continually applying the material is the only way to retain the knowledge, cramming just doesn’t work.	Explains why students should work problems the day they cover the concept in class form the prior sentence: to retain knowledge. Again appeals to students to form good study habits: work problems daily rather than cramming. Applying the material refers to "working problems" in the prior sentence (8).

B	10	You need to do the problems YOURSELF- don't just watch someone else do the problem, don't just read the worked sample problems in the text, and just don't look over solution manuals.	This sentences continues the theme of "struggling" with problems outside of class from Sentence B2. Capitalization of YOURSELF shows emphasis followed by clarification of what this means. Again uses rhetorical technique of repeating "don't just" three times to clarify what doing problems yourself does not mean. This is also an authoritative means for Professor N to make visible to students that she knows how and in what ways they would like to do problems. In other words, Professor N is identifying and positioning the collective as students who do not what to struggle.
B	11	Actually struggle with the material on your own- this helps you form your own understanding and again, make that content part of your knowledge base.	Continues and concludes theme from prior sentence. Reiterates that students need to struggle on their own to make their knowledge (or lack thereof) visible to themselves. She is promoting reflective thinking. With Sentence 3, she is promoting reflexive thinking.
B	12	And lastly, if you are having trouble understanding the material, can't work the problems and feel lost, COME SEE ME RIGHT AWAY, come to office hours or make an appointment with me.	Explains the danger signs of a student who needs help. Capitalization of "COME SEE ME RIGHT AWAY" emphasizes urgency in getting one-on-one help from the instructor as soon as possible. Implies that this is the responsibility of the student to take an active role in their own learning. Also positions working of problems as a "make it or break it" element in this course.
B	13	Don't put off getting help until after you've flunked a quiz or an exam.	Reiterates the urgency of getting help as soon as a problem is recognized by the student. Positions students as typically only recognizing that they need help after flunking an exam or quiz.
B	14	Come see me anytime you feel lost and need help understanding the material.	With prior two sentences, offers her help at anytime.

*Sections A and B are identified in Appendix J3, Achieving Success in Chem124

activity. This suggests a relationship where applying concepts constitutes part of problem solving.

In Section B, Professor N explained what students should do and not do with respect to problem solving outside of class. The themes in sentences B2 to B11 focus on the need for students to "struggle" with problems (Sentence B2, Table 21) in order for students to "form [their] own understandings and make the content part of [their] knowledge base" (Sentence B11, Table 21). However, what "struggle" means is not clear in this document. Like Section A, this section provides guidance to foreshadow what successful problem solving looks like from the instructor's point of view such as "your goal is to be able to read a problem and immediately know how to solve it" (B4), and "you need to do the problems yourself" (B10). The way that "applying" the material is referenced in Sentence B9 infers that "applying" is synonymous with doing problems.

Analysis of contributions of instructor guidance. The purpose of this section is to add contributions from the instructor’s verbal guidance in class to this developing “text” for problem solving that was initiated in the course documentation. To locate areas of interest in the video records where the instructor provided this guidance about problem solving, I consulted the observation tables in the first week of the course. I selected the first week of the course because this was when the instructor oriented students to class documentation, making explicit her norms and expectations, roles and relationships, and rules and obligations for the class. Additionally, the instructor oriented students to major events (e.g., lecture, lab, assessments) and activities (e.g., doing problems, lecturing). Of these three days, four sections of the video records of the first and third days were identified for further analysis. Selection of video records was based on where the instructor provided general guidance for problem solving practices (outside of specific chemistry content)

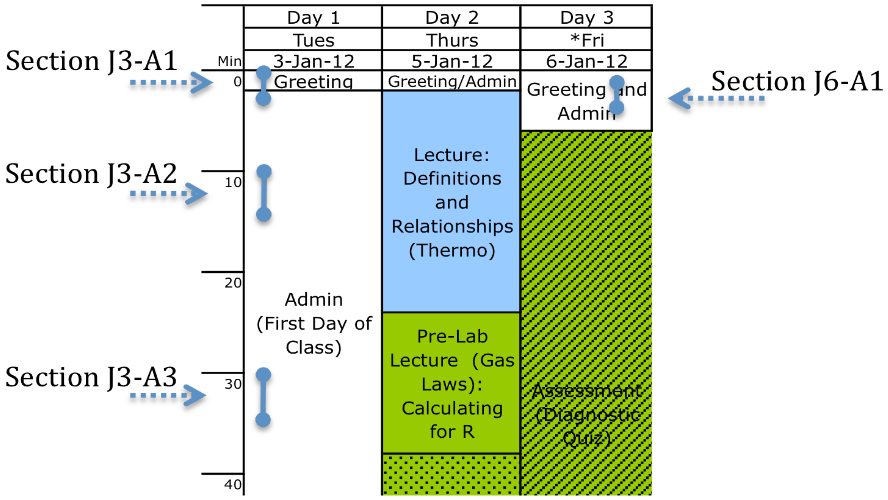


Figure 24. Approximate times of video sections identified for discourse analysis. The sections are identified by two letter and number codes representing date and section number. The first letter and number code represents month and day. The second letter and number code is an archival code to locate the section within the video archive and corresponding transcript in Appendices J (for Day 1) and K (for Day 3). For example, Section J3-A1 was recorded on January 3rd and can be traced to the first segment on that day.

to the class. Figure 24 locates these sections within a portion of the event map (Figure 12) showing the first 40 minutes of each day for the first three days.

The taxonomic map in Figure 25 visually summarizes how and in what ways the instructor positioned problem solving practices. This representation was constructed by identifying the information pertinent to problem solving in Figure 23 and (re)presenting these with problem solving as the central hub. Specifically, this

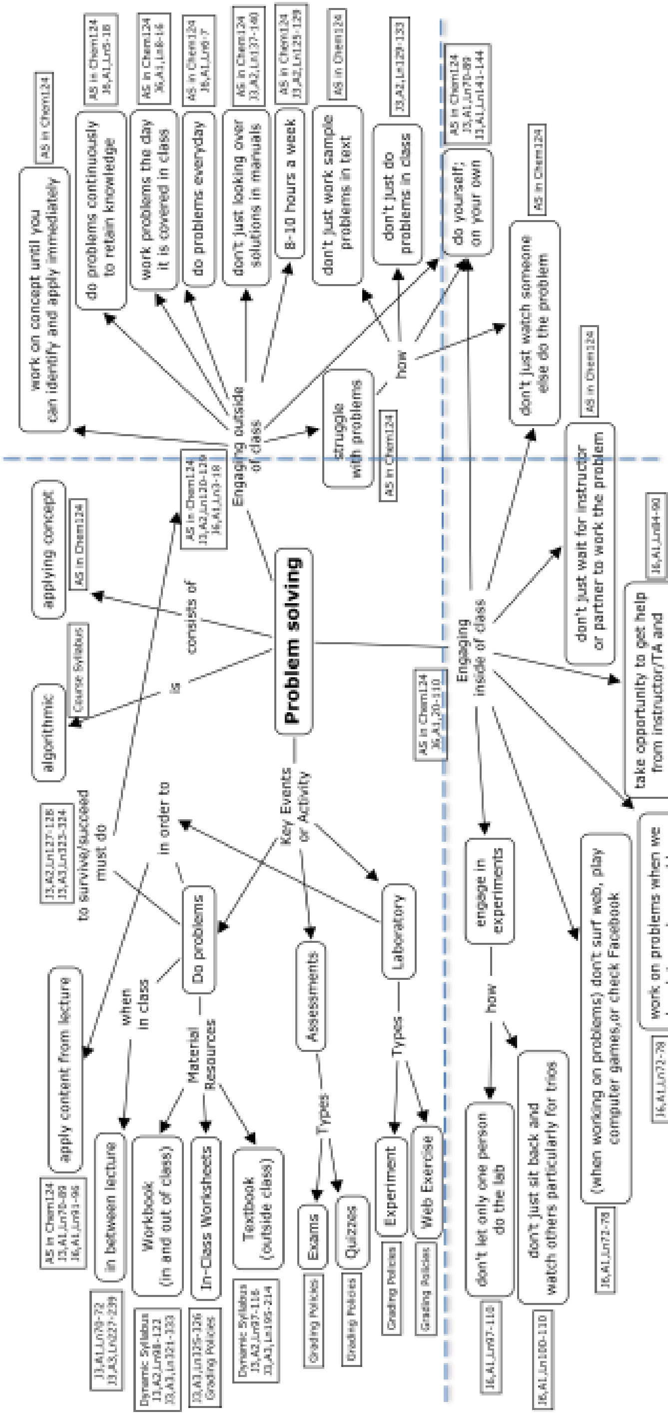


Figure 25. Taxomomic analysis showing in what ways the instructor positioned problem solving in course documentation and in instructor comments in the first week of the course.

consisted of constructing a transcript of each section identified in Figure 24 from the video record on Days 1 and 3, identifying problem solving elements and relationships through a taxonomic analysis of discourse from the transcripts, and then adding these elements and relationships on the taxonomic map for problem solving (Figure 25). Additionally within Figure 25, the documentation or transcript references are annotated in a blocked shape for each problem solving element. Transcripts were constructed as discussed in the method section of this study (see Chapter III).

Analysis of the positioning of "problem solving". The taxonomic map in Figure 25 is divided into three main areas. The areas to the right of the vertical line and below the horizontal line show how students should engage with problem solving practices (inside the class, outside of class, and both inside and outside of class). These areas show the guidance provided by Professor N for how students should position themselves in relationship with problem solving in this course. The fourth area highlights the areas of events, activity, and material resources where the problems relevant to this class can be found. Each of these areas is discussed in this section.

Elements on the right side of the dashed vertical line are related to engaging in problem solving outside of class. These elements are found mainly in the Achieving Success in Chem 124 guidance and in the instructor's verbal guidance on Days 1 and 3. Many of these elements are present in both sources, especially with respect to the duration, frequency, and timeliness of engaging in problem solving activity. Even more, doing problems consistently on a daily basis and working problems the day they are covered in class were part of Professor's N guidance on Day 3 (identified as J6 in the references in Figure 25). In positioning problem solving in this course, these reoccurring messages to students from Professor N at different times and different modes reinforced these elements as significant.

Elements below the horizontal dashed line are related to engaging in problem solving activity inside of class. Specifically, these elements are mainly concerned with what students should do when working on workbook problems in class. Professor N explained on Day 1 (Appendix K, J3-A1, Ln70-75 and J3-A3, Ln 227-239) that students would work on problems in between lecture events. However, she did not provide her intent for how they should engage with these problems until Day 3 (Appendix K, J6-A1, Lns 72-78 and 84-90).

There are three elements that apply to engaging in problem solving both inside and outside the classroom located in the lower right quadrant made by the intersecting dashed lines in the figure. These three elements (doing problems on your own, not just watching someone else do the problem, and not just waiting for the instructor or lab-partner to do the problem) are explained in the Achieving Success in Chem 124 document with respect to an expectation that students should "struggle" with the material outside of the classroom. However, doing problems "on your own" was the only element of these three that Professor N stressed in her introduction to the class. Within the framing of "struggle" provided by the instructor, it remains unclear what "struggle" means. The only guidance provided in the Achieving Success in Chem 124 document is that "struggle" is synonymous with doing problems "on your own".

Problem solving related events, activity and resources. The last major area located in the upper right quadrant of the Figure 25 identifies where and with what resources student will engage in problem solving practices in key events or activity in the course. Inside of class, problem solving occurs when students do workbook problems or in-class worksheets in between (or adjacent to) lecture events. Outside of class, students have access to recommended textbook problems as well as those in the workbook and any worksheets that has been handed out in class. In class, students engaged in problem solving activity when doing workbook problems and in-class worksheets.

Summary of Research Question 3. Within the course documentation and in Professor N's introduction to the course on Days 1 and 3, Professor N made visible her expectations and recommendations for how students should engage in a critical activity that she called "problem solving". As a result, the purpose of this section was to situate "problem solving" in relation to events, activity, resources, and actors (students, TAs, and instructor) as proposed by Professor N within course documentation and her introduction to the class on Days 1 and 3. Figure 25 provides a visual summary of how "problem solving" was situated or positioned in relationship with events, activity, resources, and ways of engagement. Specifically, this makes visible the proposed framework for when and where it occurs, with what resources and expected or desired outcome.

Salient findings from this question are the following:

1) Course documentation and instructor guidance suggest that successful performance in this course required students to spend significant time and effort in doing problems outside of class. Effort is characterized as "struggling" although it is not clear what this means.

2) The term "applying concepts" as used in the course documentation constituted an essential part of "problem solving".

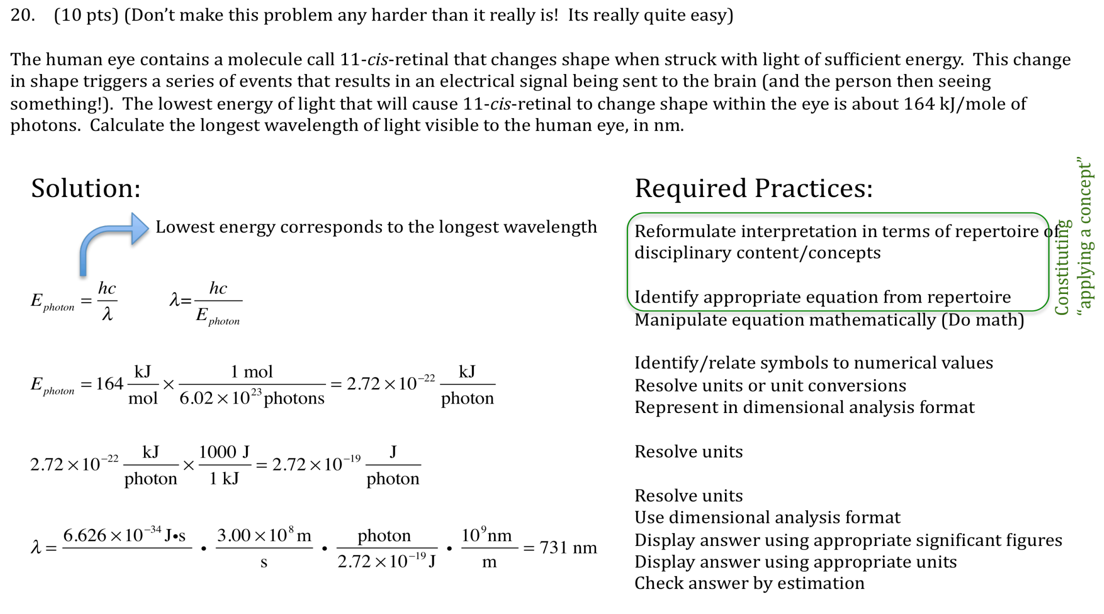
3) The recommended practices for applying concepts and doing problems from the course documentation and instructor guidance were proposed at the beginning of the course in order to situate students towards culturally appropriate problem solving practices from the instructor's perspective.

However, this taxonomic map (Figure 25) that proposes a frame for problem solving practice for students is not based on evidence of what occurred in the course. In other words, what the documentation and the instructor say *about* problem solving does not show how these practices manifested in everyday classroom life. The next question explores the complex nature of identifying and characterizing problem solving practices, with particular focus on applying concepts, within everyday life of this general chemistry course in a studio learning environment.

Research Question 4. In what ways was select disciplinary content proposed and negotiated by participants over time in collective activity?

Locating problem solving practices in the interactional spaces, events, and activity in daily life in this class could be a very complex endeavor considering that, as has been suggested by prominent scholars in the field of problem solving in chemistry, doing chemistry *is* problem solving (Bodner & Herron, 2002). So rather than examine problem solving generally, in this question, I first focus on select disciplinary content on Exam 2 as an anchor for tracing how participants constructed the required problem solving practices for students to apply one concept in Exam 2. The anchoring event was introduced at the beginning of this chapter and is analyzed in detail to initiate the trace of disciplinary content. The trace of disciplinary content provides the grounding for the next analysis in Research Question 5 examining how and in what ways problem solving practices, specifically applying concepts, manifest in table group interactions.

Figure 26 shows Problem 20 in Exam 2, the anchoring element in this analysis, and the solution to the problem with the practices required in each major step of the calculation.



20. (10 pts) (Don't make this problem any harder than it really is! Its really quite easy)

The human eye contains a molecule call 11-*cis*-retinal that changes shape when struck with light of sufficient energy. This change in shape triggers a series of events that results in an electrical signal being sent to the brain (and the person then seeing something!). The lowest energy of light that will cause 11-*cis*-retinal to change shape within the eye is about 164 kJ/mole of photons. Calculate the longest wavelength of light visible to the human eye, in nm.

Solution:	Required Practices:
Lowest energy corresponds to the longest wavelength $E_{photon} = \frac{hc}{\lambda}$ $\quad \lambda = \frac{hc}{E_{photon}}$	Reformulate interpretation in terms of repertoire of disciplinary content/concepts Identify appropriate equation from repertoire Manipulate equation mathematically (Do math)
$E_{photon} = 164\,\frac{\text{kJ}}{\text{mol}} \times \frac{1\text{ mol}}{6.02\times10^{23}\text{photons}} = 2.72\times10^{-22}\,\frac{\text{kJ}}{\text{photon}}$	Identify/relate symbols to numerical values Resolve units or unit conversions Represent in dimensional analysis format
$2.72\times10^{-22}\,\frac{\text{kJ}}{\text{photon}} \times \frac{1000\text{ J}}{1\text{ kJ}} = 2.72\times10^{-19}\,\frac{\text{J}}{\text{photon}}$	Resolve units
$\lambda = \frac{6.626\times10^{-34}\,\text{J}\bullet\text{s}}{} \bullet \frac{3.00\times10^{8}\,\text{m}}{\text{s}} \bullet \frac{\text{photon}}{2.72\times10^{-19}\,\text{J}} \bullet \frac{10^{9}\text{nm}}{\text{m}} = 731\text{ nm}$	Resolve units Use dimensional analysis format Display answer using appropriate significant figures Display answer using appropriate units Check answer by estimation

Figure 26. Required solution and practices to complete Problem 20 in Exam 2.

The disciplinary concept focuses on the relationship between energy (*E*) and wavelength (λ) which is represented by the equation:

$$E = \frac{hc}{\lambda} \qquad \text{(Equation 1)}$$

where *h* is Planck's constant and *c* is the speed of light, both constant variables. This relationship is foundational to understanding the wave properties of light as the basis for how the chemistry discipline models atomic structure using quantum theory.

Each step in the solution process is shown explicitly in Figure 26 with the corresponding practices required for each section of the solution. Essentially, these knowledge requirements can be categorized into two types (see Figure 27). The first type requires students to interpret the problem in terms of domain specific knowledge. Students were required to reformulate their interpretation of the problem into a mathematical representation of the required concept. In this study, a reformulation of a concept is integrating the application of the concept for self so then it may be applied in a situated and purposeful way (J. Green, email correspondence, January 3, 2013). In Problem 20, students must recognize that this situation, which they have not experienced in the course, is an application of Equation 1. The second type of required knowledge to do this problem is procedural knowledge. This is knowledge of the practices required for the remainder of the problem, essentially what the instructor called "chemical math". These involved conversions such as the number of molecules to the number of its chemical elements (stoichiometry) and other unit-type conversions such as kilojoules (kJ) to joules (J). Additionally, in order to count as a valid solution, students were required to “show their work”, including displaying conversions and showing the final answer in the appropriate format of significant figures and required units (nanometers, nm). In this way, after applying the appropriate concept (Equation 1) for this problem, the remaining work required students to display culturally constructed representations for what counts as a valid solution to this type of problem in this course.

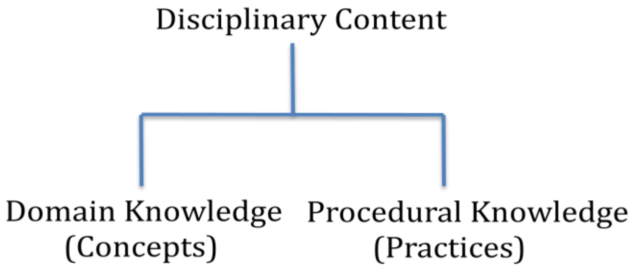


Figure 27. Disciplinary content conceptualized as both domain knowledge and procedural knowledge.

Closely related to Equation 1 is the Ryberg equation for atomic spectra:

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \text{ where } n_2 > n_1 \text{ and } R = 1.097 \times 10^7 m^{-1} \quad \text{(Equation 2)}$$

The Ryberg equation represents the relationship between wavelength (λ) and the transition between select energy levels (n_1, n_2) for hydrogen only. Equation 2 is used for determining the wavelengths of observed line spectra characteristic of the various elements. Both Equations 1 and 2 represent the target concepts in this portion of the study. These relate energy, wavelength, and energy levels in a one electron atom.

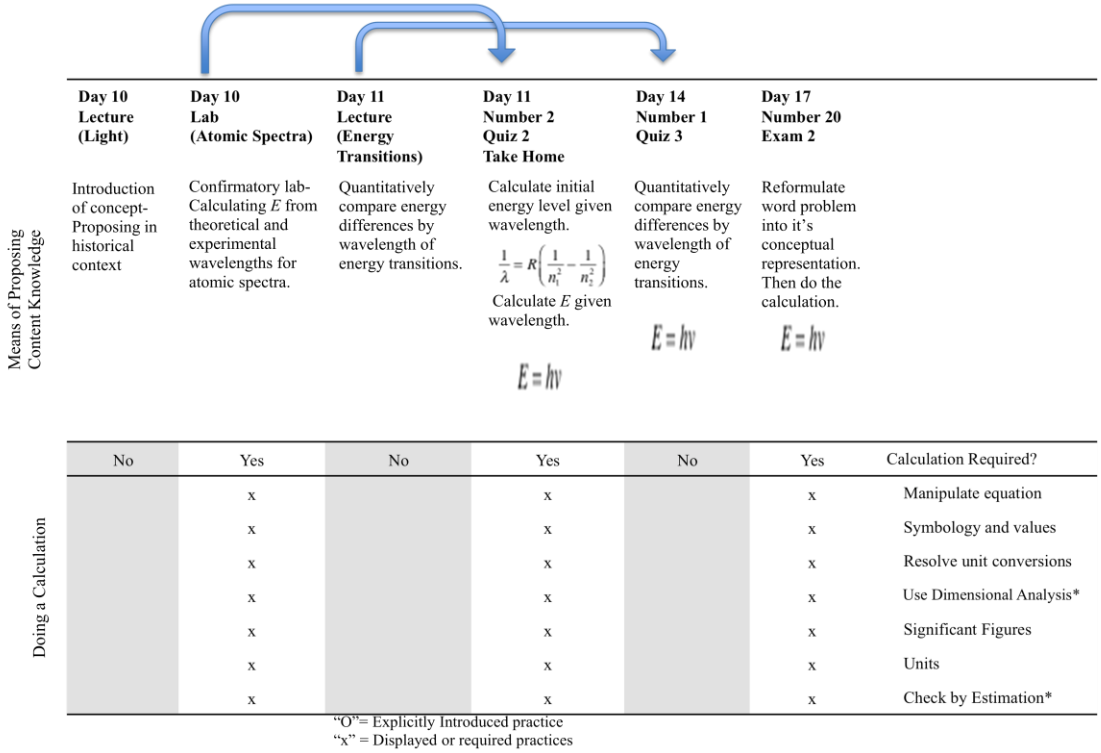
The domain knowledge and procedural knowledge required of a student to successfully complete Problem 20 on the exam were presumably proposed in prior class activity. The next section traces how and in what ways these concepts and practices were proposed in the class.

Table 24 shows the trace of concepts and practices in 2nd Exam Cycle of Activity that were developed in the analysis of Problem 20 of Exam 2 (Figure 26). This content based in this foundational equation for energy (Equation 1) was application of Equation 1 and 2 to atomic spectra was required in Quiz 2, a take home assessment that was given to students on Day 11 and due on Day 12. These concepts were then used to determine relative energies (qualitatively) in energy transitions in a lecture event on Day 11. Applying this concept within the context of determining relative energies was required in Quiz 3 on Day 14. The same practices required for Problem 20 in Exam 2 were required during the Atomic Spectra Lab on Day 10 and Question 1 of Quiz 2. These were all calculations (quantitative) based questions. However, none of the practices for doing calculations were introduced (for the first time) during the 2nd exam cycle of activity. Tracing of practices for doing calculations will be discussed after the trace of concepts by event.

Trace of disciplinary concepts by event. Table 24 shows the events and, in a very general sense, how these events contributed to building problem solving capacity for applying Equations 1 and 2. Problem solving capacity is the potential for, in this case, a chemistry community of learners or an individual student to apply knowledge to solve problems. Problem solving capacity is constructed from student take up

Table 24

Trace of Disciplinary Concepts and Practices for Problem 20 of Exam 2 in the 2nd Exam Cycle of Activity



	Day 10 Lecture (Light)	**Day 10 Lab (Atomic Spectra)**	**Day 11 Lecture (Energy Transitions)**	**Day 11 Number 2 Quiz 2 Take Home**	**Day 14 Number 1 Quiz 3**	**Day 17 Number 20 Exam 2**	
Means of Proposing Content Knowledge	Introduction of concept-Proposing in historical context	Confirmatory lab-Calculating *E* from theoretical and experimental wavelengths for atomic spectra.	Quantitatively compare energy differences by wavelength of energy transitions.	Calculate initial energy level given wavelength. $\frac{1}{\lambda}=R\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$ Calculate *E* given wavelength. $E=h\nu$	Quantitatively compare energy differences by wavelength of energy transitions. $E=h\nu$	Reformulate word problem into it's conceptual representation. Then do the calculation. $E=h\nu$	
Doing a Calculation	No	Yes	No	Yes	No	Yes	Calculation Required?
		x		x		x	Manipulate equation
		x		x		x	Symbology and values
		x		x		x	Resolve unit conversions
		x		x		x	Use Dimensional Analysis*
		x		x		x	Significant Figures
		x		x		x	Units
		x		x		x	Check by Estimation*

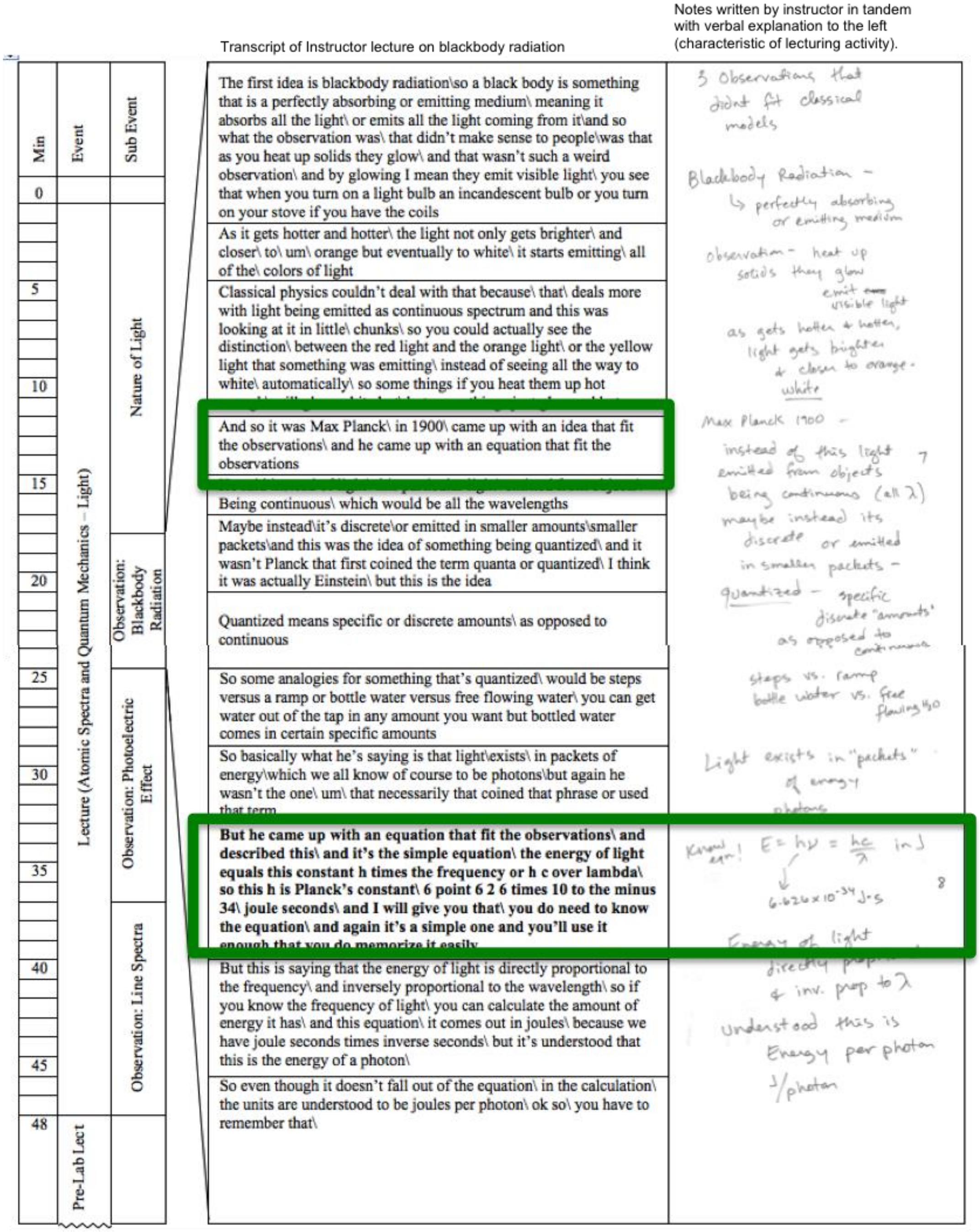
"O"= Explicitly Introduced practice
"x" = Displayed or required practices

of disciplinary concepts and practices as they use concepts in trying to solve problems. This section takes a more detailed perspective of examining each of the first six events shown in Table 24 individually to show how participants collectively proposed and negotiated what was required to do a problem. The first three events are on Day 10. The last three events are on Days 11 and 14.

The first three events, lecture on light, pre-lab lecture, and lab on atomic spectra occurred on Day 10. The event map for this day is shown in Figure 12. A pullout table showing the flow of activity in engaging with the disciplinary content was shown in Figure 21a and discussed in the section "Designing for historical development of quantum theory" (page 105 of this study).

Proposing Concepts in Lecture Event: Light (Day 10). Figure 28 shows how Equations 1 and 2 were proposed in the lecturing activity on light on Day 10. The figure locates the introduction of these equations by sub-events within the lecture on light with select pullouts for Equations 1 and 2. The pullouts show the transcript of the instructor proposing this content with her written notes shown to the right. This table was constructed such that the writing and discourse are synced horizontally as much as is possible with this type of representation.

In accordance with the unfolding of information proposed by the instructor shown in Figure 28, Equation 1 was proposed in a historical context (top blocked area in Figure 28) as the first of three key observations that made scientists think about the nature of light in different ways from classical models (light as being emitted as a continuous spectrum). As shown in the lower blocked area, students were required to “know this” equation as written in the notes next to the equation (Figure 28). As the instructor wrote this equation in the notes, she explained that she would provide the values of the constant variables. However, she explained that she would not provide the key equation, Equation 1, in the assessment when she said, “you do need to know the equation and again it’s a simple one and you’ll use it enough that you do



Transcript of Instructor lecture on blackbody radiation	Notes written by instructor in tandem with verbal explanation to the left (characteristic of lecturing activity).
The first idea is blackbody radiation\so a black body is something that is a perfectly absorbing or emitting medium\ meaning it absorbs all the light\ or emits all the light coming from it\and so what the observation was\ that didn't make sense to people\was that as you heat up solids they glow\ and that wasn't such a weird observation\ and by glowing I mean they emit visible light\ you see that when you turn on a light bulb an incandescent bulb or you turn on your stove if you have the coils	3 Observations that didnt fit classical models Blackbody Radiation – ↳ perfectly absorbing or emitting medium
As it gets hotter and hotter\ the light not only gets brighter\ and closer\ to\ um\ orange but eventually to white\ it starts emitting\ all of the\ colors of light	observation – heat up solids they glow emit visible light
Classical physics couldn't deal with that because\ that\ deals more with light being emitted as continuous spectrum and this was looking at it in little\ chunks\ so you could actually see the distinction\ between the red light and the orange light\ or the yellow light that something was emitting\ instead of seeing all the way to white\ automatically\ so some things if you heat them up hot	as gets hotter & hotter, light gets brighter & closer to orange - white
And so it was Max Planck\ in 1900\ came up with an idea that fit the observations\ and he came up with an equation that fit the observations	Max Planck 1900 – instead of this light emitted from objects being continuous (all λ) 7
Being continuous\ which would be all the wavelengths	
Maybe instead\it's discrete\or emitted in smaller amounts\smaller packets\and this was the idea of something being quantized\ and it wasn't Planck that first coined the term quanta or quantized\ I think it was actually Einstein\ but this is the idea	maybe instead its discrete or emitted in smaller packets –
Quantized means specific or discrete amounts\ as opposed to continuous	quantized – specific discrete "amounts" as opposed to continuous
So some analogies for something that's quantized\ would be steps versus a ramp or bottle water versus free flowing water\ you can get water out of the tap in any amount you want but bottled water comes in certain specific amounts	steps vs. ramp bottle water vs. free flowing H_2O
So basically what he's saying is that light\exists\ in packets of energy\which we all know of course to be photons\but again he wasn't the one\ um\ that necessarily that coined that phrase or used that term	Light exists in "packets" of energy photons
But he came up with an equation that fit the observations\ and described this\ and it's the simple equation\ the energy of light equals this constant h times the frequency or h c over lambda\ so this h is Planck's constant\ 6 point 6 2 6 times 10 to the minus 34\ joule seconds\ and I will give you that\ you do need to know the equation\ and again it's a simple one and you'll use it enough that you do memorize it easily	Know eqn! $E = h\nu = \frac{hc}{\lambda}$ in J 6.626×10^{-34} J·s 8
But this is saying that the energy of light is directly proportional to the frequency\ and inversely proportional to the wavelength\ so if you know the frequency of light\ you can calculate the amount of energy it has\ and this equation\ it comes out in joules\ because we have joule seconds times inverse seconds\ but it's understood that this is the energy of a photon\	Energy of light directly prop & inv. prop to λ understood this is Energy per photon J/photon
So even though it doesn't fall out of the equation\ in the calculation\ the units are understood to be joules per photon\ ok so\ you have to remember that\	

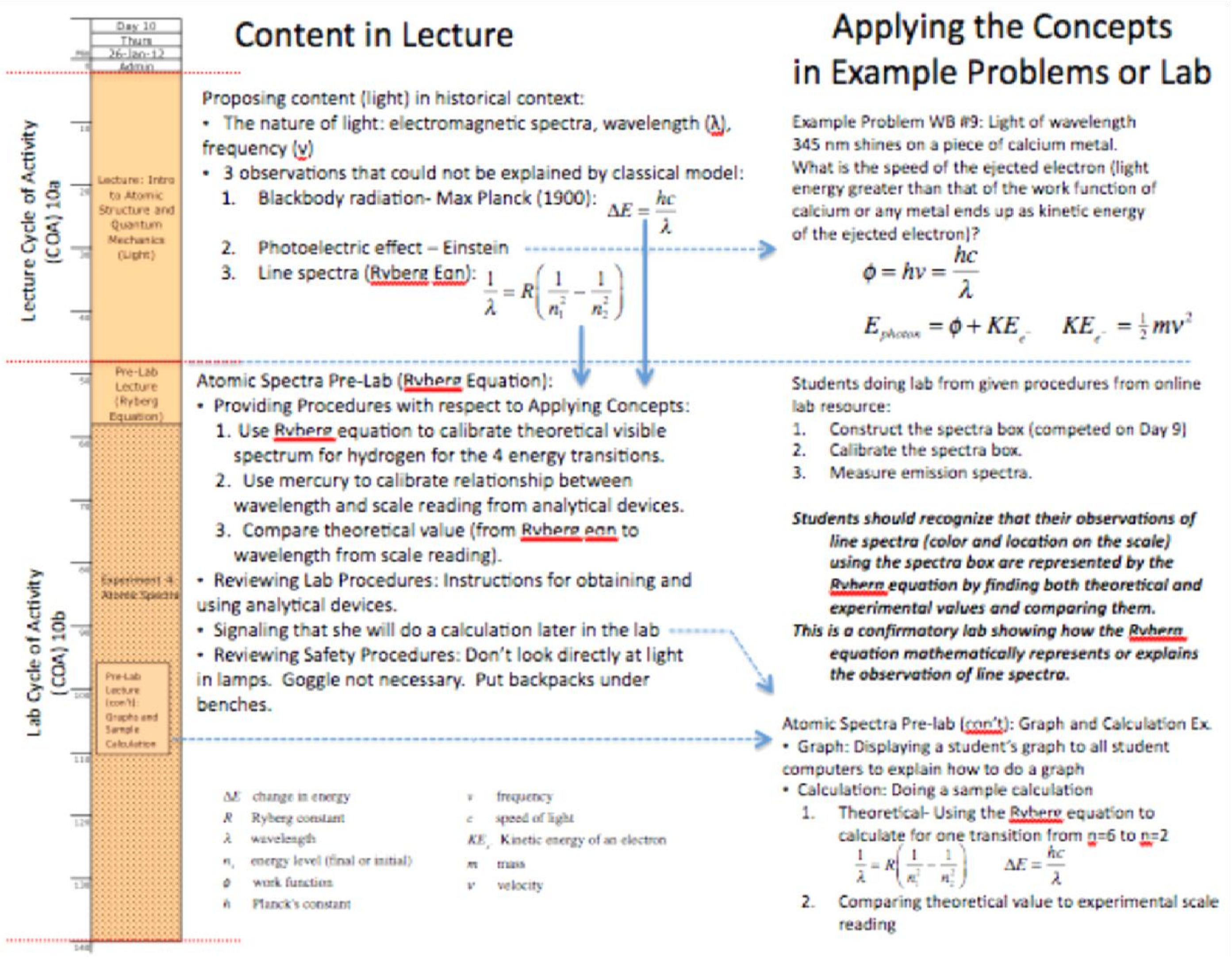
Figure 28. Introduction of key concept (Equation 1) during a lecture event on Day 10.

memorize it easily" (Figure 28). This statement also draws significance to Equation 1, such that students should memorize it, unlike most other equations that are provided in an equations list on exams and quizzes. Equation 2, the Ryberg Equation, was also introduced in the same way from minutes 37 to 48 in the lecture on line spectra. In this lecture event, Equations 1 and 2 were not used to solve a problem. Rather, these were used in the next major cycle of activity in Day 10, the lab cycle of activity.

Using concepts in a Lab Cycle of Activity: Atomic Spectra (Day 10). Figure 29 is another representation showing how these concepts were proposed in the lecture event on Day 10 and how these concepts (Equations 1 and 2) fed into the next major lab cycle of activity on the same day. As shown, the lab cycle of activity consisted of two events: the pre-lab lecture event and the lab event.

The first event in the lab cycle of activity was the pre-lab lecture. A summary of content provided in the pre-lab lecture is provided in Figure 29. In the pre-lab lecture, the instructor drew on Equations 1 and 2 that she introduced in the immediately preceding lecture event (shown as downward solid arrows from Equations 1 and 2) to explain, in procedural terms, how these equations are applied in the lab. Also, in this pre-lab lecture the instructor introduced Equation 3 as the combination of Equations 1 and 2 relating energy directly to transitions between select energy levels (for hydrogen only):

$$E = -2.18 \times 10^{-18}\,J\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \qquad \text{(Equation 3)}$$



Content in Lecture

Proposing content (light) in historical context:

- The nature of light: electromagnetic spectra, wavelength (λ), frequency (v)
- 3 observations that could not be explained by classical model:
  1. Blackbody radiation- Max Planck (1900): $\Delta E = \frac{hc}{\lambda}$
  2. Photoelectric effect – Einstein
  3. Line spectra (Rybere Eqn): $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

Atomic Spectra Pre-Lab (Ryberg Equation):

- Providing Procedures with respect to Applying Concepts:
  1. Use Ryberg equation to calibrate theoretical visible spectrum for hydrogen for the 4 energy transitions.
  2. Use mercury to calibrate relationship between wavelength and scale reading from analytical devices.
  3. Compare theoretical value (from Ryberg eqn to wavelength from scale reading).
- Reviewing Lab Procedures: Instructions for obtaining and using analytical devices.
- Signaling that she will do a calculation later in the lab
- Reviewing Safety Procedures: Don't look directly at light in lamps. Goggle not necessary. Put backpacks under benches.

ΔE	change in energy	v	frequency
R	Ryberg constant	c	speed of light
λ	wavelength	KE_e	Kinetic energy of an electron
n_i	energy level (final or initial)	m	mass
ϕ	work function	v	velocity
h	Planck's constant		

Applying the Concepts in Example Problems or Lab

Example Problem WB #9: Light of wavelength 345 nm shines on a piece of calcium metal. What is the speed of the ejected electron (light energy greater than that of the work function of calcium or any metal ends up as kinetic energy of the ejected electron)?

$$\phi = hv = \frac{hc}{\lambda}$$

$$E_{photon} = \phi + KE_{e^-} \qquad KE_{e^-} = \tfrac{1}{2}mv^2$$

Students doing lab from given procedures from online lab resource:

1. Construct the spectra box (competed on Day 9)
2. Calibrate the spectra box.
3. Measure emission spectra.

Students should recognize that their observations of line spectra (color and location on the scale) using the spectra box are represented by the Ryberg equation by finding both theoretical and experimental values and comparing them.

This is a confirmatory lab showing how the Ryberg equation mathematically represents or explains the observation of line spectra.

Atomic Spectra Pre-lab (con't): Graph and Calculation Ex.

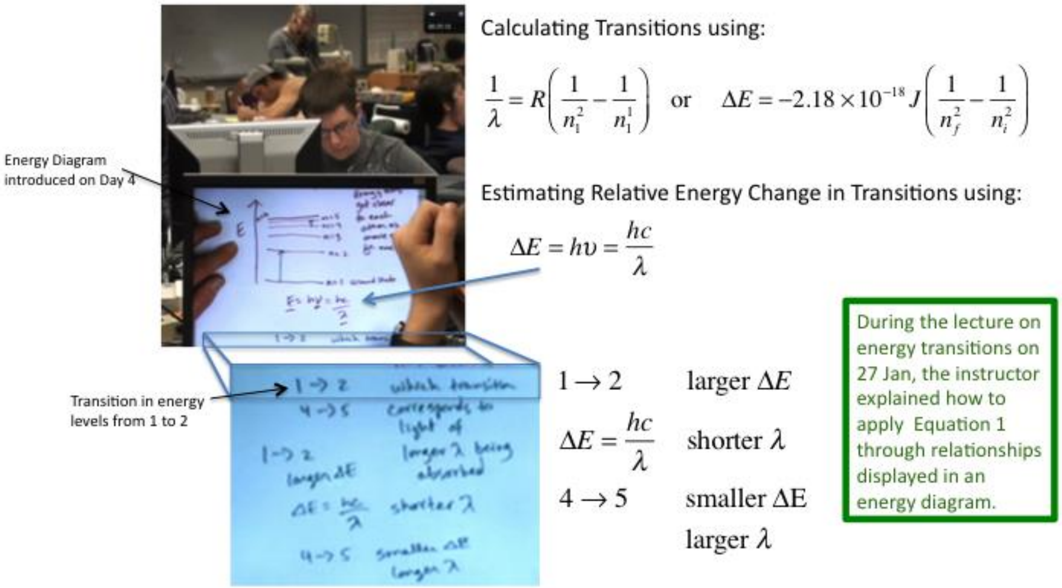
- Graph: Displaying a student's graph to all student computers to explain how to do a graph
- Calculation: Doing a sample calculation
  1. Theoretical- Using the Ryberg equation to calculate for one transition from n=6 to n=2
     $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \qquad \Delta E = \frac{hc}{\lambda}$
  2. Comparing theoretical value to experimental scale reading

Figure 29. Content and application of concepts contributing to lab Cycle of Activity 10b.

Part of what is required in applying content to Problem 20 of Exam 2 is to differentiate between the application of Equation 1 and Equations 2 and 3. Equation 1 relates energy to wavelength and Equations 2 and 3 relate energy or wavelength to a specific energy transition. The pre-lab lecture also includes a review of the lab procedures for using the analytical instrument as well as safety guidelines which are common elements in other pre-lab lectures (see Figure 17 in Chapter 4). Professor N also mentioned that she planned to interrupt the lab event with a lecturing activity to show students how to do the calculations.

The second event in the lab cycle of activity (Figure 29) is the lab event on atomic spectra. The lab was a confirmatory lab where students were required to compare theoretical (calculated) wavelengths and energies for the transitions of hydrogen gas to experimentally derived wavelengths and energies. With the guidance provided by the instructor in the pre-lab lecture and the lab online resources, students first gathered data to construct their calibration graphs to relate the scale readings from their analytical instruments to wavelength by Equation 2 or directly to energy by Equation 3. Some students began doing calculations before Professor N took control of the computer monitors and demonstrated how to use Equations 1 and 2 in a sample calculation for one of the theoretical (derived by calculation) wavelengths of hydrogen gas. Following this lecture activity, students reoriented on their own calculations and continued the lab.

Using concepts in a lecture event: Energy Transitions (Day 11). The short lecture on Day 11 is an extension of ways that Equations 1 and 2 can be applied with respect to energy transitions. Up to this point, Equations 1 and 2 had been used to quantitatively relate energy and wavelength to energy level transitions. Drawing on the basic format of the energy diagram which had been introduced for use in thermodynamics on Days 4 and 5, the instructor used this representation to show relative energy differences (ΔE) between energy levels which then show the relative wavelengths through Equation 1. Central to these relationships is that as energy levels (n) increase, the difference in energy (ΔE) between levels decreases as shown in the frame grab in Figure 30.



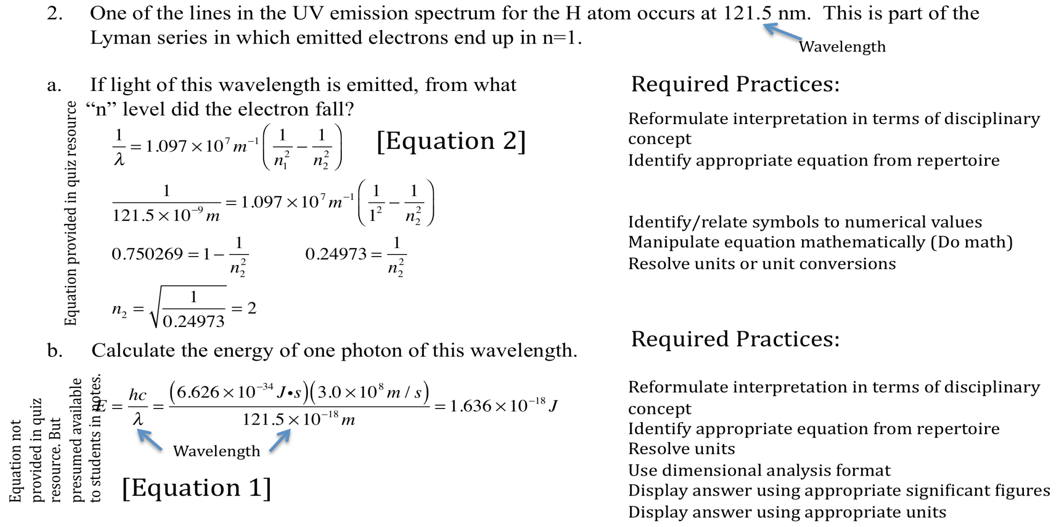
During the lecture on energy transitions on 27 Jan, the instructor explained how to apply Equation 1 through relationships displayed in an energy diagram.

Figure 30. The frame grab shows Professor N writing notes which are displayed in real time to all student monitors as she explained the content during a lecture event on Day 11. Professor N applied Equation 1 to estimate the relative energy change for electron transitions between energy levels (n). The expansion of notes from the frame grab shows how this concept was applied to discerning relative wavelengths (λ).

Applying concepts in quiz events (Days 11 and 14). Thus far in the tracing of the introduction and use of Equations 1 and 2 in this course, these equations (representing the target concepts) were introduced in a lecture event on Day 10 and then used quantitatively in the atomic spectra lab on Day 10 and qualitatively in the energy transitions lecture on Day 11. Now I show how these are applied in the next class events: quizzes on Days 11 and 14.

Quiz 2 (Day 11) was the only quiz or exam event in the six weeks of data collection in this study which did not take place within the formal class time. Due to a missed day due to a holiday in week 3, the instructor chose to adjust this planned in-class event to a take-home quiz so that she could spend the class time on proposing content in lecture events. As such, the “typical” exam or quiz on Fridays was replaced with more content on Day 11. Students were given the quiz at the end of Day 11 (Friday, Week 4) and it was due at the beginning of class on Day 12 (Monday, Week 5).

Figure 31 shows Problem 2 of Quiz 2 with the solution and list of practices required to do the problem. The question is asked in Part A (find energy level "n" given wavelength) and Part B (calculate energy given wavelength). Problem 2 of Quiz 2 (Figure 31) mirrored what was required of students in the atomic spectra lab on Day 10. Given a wavelength (which students determined from their calibration graph in the lab), Part A of the question required students to use Equation 2 to find the initial energy level (n_1). Then, Part B required students to find the energy using Equation 1 given the wavelength.



2. One of the lines in the UV emission spectrum for the H atom occurs at 121.5 nm. This is part of the Lyman series in which emitted electrons end up in n=1.

Wavelength

a. If light of this wavelength is emitted, from what "n" level did the electron fall?

$$\frac{1}{\lambda} = 1.097 \times 10^{7} m^{-1}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

[Equation 2]

$$\frac{1}{121.5 \times 10^{-9} m} = 1.097 \times 10^{7} m^{-1}\left(\frac{1}{1^2} - \frac{1}{n_2^2}\right)$$

$$0.750269 = 1 - \frac{1}{n_2^2} \qquad 0.24973 = \frac{1}{n_2^2}$$

$$n_2 = \sqrt{\frac{1}{0.24973}} = 2$$

Equation provided in quiz resource

Required Practices:

Reformulate interpretation in terms of disciplinary concept
Identify appropriate equation from repertoire

Identify/relate symbols to numerical values
Manipulate equation mathematically (Do math)
Resolve units or unit conversions

b. Calculate the energy of one photon of this wavelength.

$$E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} J \bullet s)(3.0 \times 10^{8} m/s)}{121.5 \times 10^{-18} m} = 1.636 \times 10^{-18} J$$

Wavelength

[Equation 1]

Equation not provided in quiz resource. But presumed available to students in notes.

Required Practices:

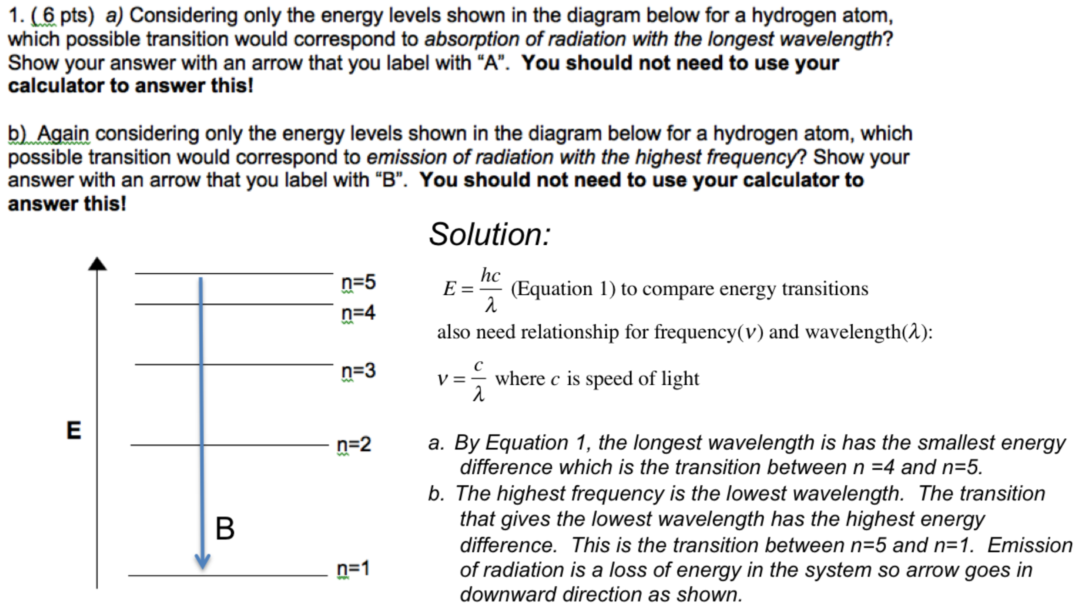
Reformulate interpretation in terms of disciplinary concept
Identify appropriate equation from repertoire
Resolve units
Use dimensional analysis format
Display answer using appropriate significant figures
Display answer using appropriate units

Figure 31. Solution and required practices for Problem 2 on Quiz 2.

However, the difference in requirements for this quiz as compared with doing this in the lab is that, in the lab, students were given the required equations *a priori* as part of the lecture and pre-lab lecture on Day 10 (Figure 29). Contrastively, in the quiz, the context for the problem must be determined from within the question itself. In other words, the conditions of this quiz required students to interpret the question such that they had to locate (from the student's problem solving capacity) the appropriate equation that represents the situation posed in the problem. In this way, *applying* the concepts (Equations 1 and 2) in the lab was markedly different then *applying* the same concepts and in the same context for the quiz.

The way that concepts were used in Problem 1 from Quiz 3 on Day 14 (Figure 31) traces back to the lecture on Day 11 (See Figure 30) where the instructor showed how the energy diagram and Equation 1 were used to determine relative magnitudes of wavelengths and energies for energy transitions of an electron. Figure 32 shows

Problem 1 on Quiz 3 and the given energy diagram with relative positions of energy levels n=1, 2, 3, 4 and 5. The solution requires that students produce Equation 1 as representative of the relationship between energy and wavelength. Note, like in Quiz 2, Equation 1 is not provided as a resource. As signaled in the lecture event on Day 10 (see Figure 28), students were expected to know (memorize) and (re)produce Equation 1. Unlike the application of content in Quiz 2 where students were required to apply the content in a lab prior to the quiz, students were not given an opportunity to apply the content qualitatively within opportunities for learning in the class prior to Quiz 3.



1. (6 pts) *a)* Considering only the energy levels shown in the diagram below for a hydrogen atom, which possible transition would correspond to *absorption of radiation with the longest wavelength*? Show your answer with an arrow that you label with “A”. **You should not need to use your calculator to answer this!**

b) Again considering only the energy levels shown in the diagram below for a hydrogen atom, which possible transition would correspond to *emission of radiation with the highest frequency*? Show your answer with an arrow that you label with “B”. **You should not need to use your calculator to answer this!**

Solution:

$E = \frac{hc}{\lambda}$ (Equation 1) to compare energy transitions

also need relationship for frequency(ν) and wavelength(λ):

$\nu = \frac{c}{\lambda}$ where c is speed of light

a. By Equation 1, the longest wavelength is has the smallest energy difference which is the transition between n =4 and n=5.

b. The highest frequency is the lowest wavelength. The transition that gives the lowest wavelength has the highest energy difference. This is the transition between n=5 and n=1. Emission of radiation is a loss of energy in the system so arrow goes in downward direction as shown.

Figure 32. Question 1 on Quiz 3 with the energy diagram for energy levels n= 1, 2, 3, 4, and 5 with a solution.

Summary of trace of disciplinary content. Figure 33 shows a summary of opportunities for learning the content required to complete Problem 20 on Exam 2 made available in the formal class periods. The first exam cycle of activity, which covered thermodynamics topics, proposed energy as heat. On Days 4 and 5, the instructor introduced and used energy diagrams with respect to changes in energy in chemical reactions as well as phases changes. The second exam cycle of activity continued the discussion about energy, but now with respect to light. Here, the instructor used the energy diagram from the first cycle of activity as a resource to show energy gained or lost in energy level transitions of an electron in an atom. This disciplinary content represented in Equations 1 and 2 provided the basis of the quantum model (theory) of atomic structure.

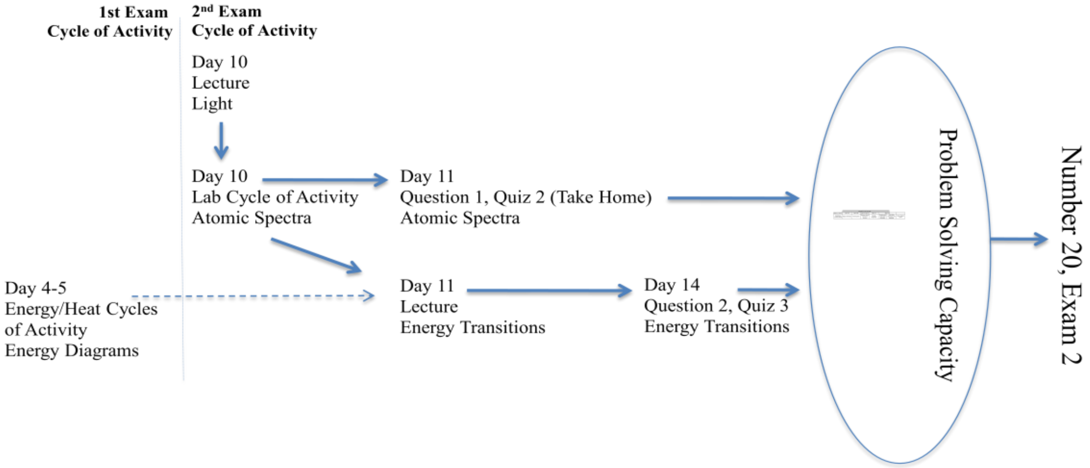


Figure 33. Summary of trace of content contributions to student problem solving capacity from in-class events for solving Question 20, Exam 2. Dotted arrows link the origin of proposed practices with proposed disciplinary content on Day 11 that were required by students a material resource.

Figure 33 is incomplete because it only shows how participants proposed and built on these concepts (characterizing energy as light and characterizing of atomic spectra as transitions between energy levels) over time as well as opportunities for applying these concepts in quiz events. Undoubtedly, taking up and applying these concepts is critical to being able to answer the target question (Problem 20, Exam 2); however, these concepts (domain knowledge) are not the only type of knowledge that students are required to display for what counts as an answer for this calculations-based question.

Tracing Practices for Doing a Calculation (Days 4 and 5). After identifying the appropriate concept and its representation, the remaining practices required to complete the problem fall in the realm of “doing a calculation". Practices required to do the calculation are procedural knowledge. As shown in Table 24 these practices were not introduced or even displayed by the instructor in her proposing of energy as light and energy transitions. Rather, students used these practices on their own in the atomic spectra lab indicating that they had taken up these practices prior to beginning the quantum theory and atomic structure cycle of activity.

Searching through the observation tables in the first exam cycle of activity, the practices for doing a calculation were introduced in lecturing and workbook problem solving sessions in the beginning of the thermodynamics cycle of activity on Days 4 and 5. Table 25 shows how and where practices affiliated with doing a calculation were signaled by Professor N as a socially significant practice (identified with “⊗”) and demonstrated through use (identified with “x”) in this chemistry class.

Table 25 shows the trace of problem solving practices introduced and/or used on Days 4 and 5 and quantitative based questions on Exam 1. From the list of practices on the left side of the table, the two shown in bold type represent using the concept (choosing the appropriate concept and appropriating the correct representation that will address the question). The remaining practices constitute "doing a calculation". Note that in several of these elements, the instructor used practices (marked with an 'x') prior to explicitly introducing these (marked with a "⊗") as socially significant to the practice of doing a calculation in this course. For example, as annotated on Day 4 in Table 25, Professor N used the dimensional analysis format to explicitly show unit and stoichiometric conversions in a gas law example problem on Day 2 and two thermodynamic example and workbook problems on Day 4.

Professor N signaled the social significance of dimensional analysis in Table 26. Lines 492-493 of Table 26, "so again/ I've included all my units", show that the listing of units (and conversions) in her solution path for Workbook Problem #20 on Day 4 was a practice that she has displayed to students prior to her doing this problem. But now she explained to students that she was showing the solution path in this way for a specific purpose. This signaled that showing work in dimensional analysis format is a socially significant practice in this course. This practice was reinforced as socially significant in quizzes and exams which required students to "show their work", not just provide a final answer (see Table 23b).

Table 25

Trace of Problem Solving Practices Introduced and/or Used on Days 4 and 5 of the 1st Exam Cycle of Activity

	Day	2	4	4	4	4	4	4	4	5	5	9	9	9
	Problem	Example	Example	WB #8	Example	WB #19b	WB #20	Example	WB #26	WB #26	WB #16	Exam 1, #18	Exam 1, #19	Exam 1, #20
	Event/Activity	Pre-lab Lecture- Gas Laws	Lecture- Enthalpy (COA1)	Workbook Problem - Enthalpy	Lecture-Thermochem Eqn	WB Prob – Stoichiometry in a Thermochemical Equation	WB Prob- Construct Thermochem Equation then Stoichiometry	Lecture: Standard Enthalpy of Reaction	Workbook Problem- Standard Enthalpy of Reaction	Lecture: Heat Capacity	Lecture: Enthalpy in phase changes	Exam 1	Exam 1	Exam 1
	Concept used within a context established *a priori* (equation or concept provided)	x	x	x	x	x	x	x	x	x	x			
Problem Solving Practices	***Reformulate interpretation of question in terms of disciplinary concept, relationship and/or symbolic representation.***			x	x	x	x		x	x	x	x	x	x
	Identify appropriate equation or construct solution path from repertoire	x			x	x	x	x	x	x	x	x	x	x
	Interpret and obtain information from a graph or produce a graph representing a concept		⊗	⊗										
	Manipulate equation mathematically (Do math)	x			x	x	x	x	x	x	x	x	x	x
	Identify/relate symbols to numerical values	x			x	x	x	x	x		x	x	x	x
	Consider/Resolve units or unit conversions	⊗			x	x	x	x	x	x	x	x	x	x
	Use dimensional analysis format (recommended)	x			x	x	⊗	x	x	x	x	x	x	x
	Display answer using appropriate significant figures	x			⊗	x	x	⊗	x	x	x	x	x	x
	Display answer using appropriate units	x			x	x	x	x	x	x	x	x	x	x
	Check answer by estimation (recommended)						⊗							

Table 26

Selection of Dialogue Where Professor N Explains Why Students Should Use Dimensional Analysis Format to Show the Solution Path for Doing the Calculation in Workbook Problem #20 on Day 4

Line	Professor N
492	so again
	I've included all of my units
	and I know that you probably
495	get tired of writing all of those units
	but it really does help
	because then when you get to the end
	of the calculation
	you've got the units you want
500	and if you messed up
	you can hopefully see
	where you messed up
	um
	and I also think it just helps you
505	organize
	if you have things up out very neatly like that

Practices for doing a calculation is an additional contributor to what is required to do Problem 20 of Exam 2. Therefore, in Figure 34, I added these in the cover term "Practices for Doing a Calculation". Figure 34 shows where the practices for doing a calculation are used by instructor and students as they proposed and used the target concepts in the quantum mechanics and atomic structure cycle of activity on Days 10 and 11. Additionally, other potential contributions to students' developing problem solving capacity in the target domain include those opportunities discussed largely in Research Question 3 for what students can and should do outside of class. These include doing workbook problems, text problems, worked examples from the textbook, and attending workshop problem solving sessions (see Figure 34).

Analysis of trace of concepts and practices. Figure 34 represents opportunities for learning what is required to address Problem 20 on Exam 2. Note that this representation can be characterized as a process of moving from *using* to *applying* content over time. References to *applying* a concept was mentioned several times by Professor N in the context of solving problems. For example, on Day 3, Professor N explained how the course functioned, "I tend to lecture in little increments\ of about 30 minutes or so\ and then we stop to do problems\ to apply what we've been\ talking about in lecture". On Day 6, Professor N suggested to students about how to engage with content in class "...and also fully engage in experiments\ because many of them\ in fact all of them\ apply what we've been talking about in lecture". Additionally, on Day 3, she proposed transitioning from lecture activity to doing a workbook problem, "ok so\ let's work on a problem\ apply what we've been talking about in lecture". Then in the Exam 2 study guide, Professor N told students, "This is a summary of the key concepts you should understand and be able to apply for Exam 2. Applying the concepts means DOING calculations" (Neff, Exam 2 Study guide). These examples show that the discourse of problem solving in this class uses the term "apply" to any use of a concept, regardless of the demands on students when working an example problem in class or working a problem in an exam.

However, this analysis shows key differences between the demands on the student in engaging in an example or workbook problem in class versus the demands on a quiz or an exam. Namely, in example or workbook problems, the concepts are provided *a priori*. I argue that these are examples of students *using* a concept because the concept is provided to them first. The lab activity or an example problem is borne from the disciplinary concept as an example of how the concept is used. In this way, when doing an example problem, students

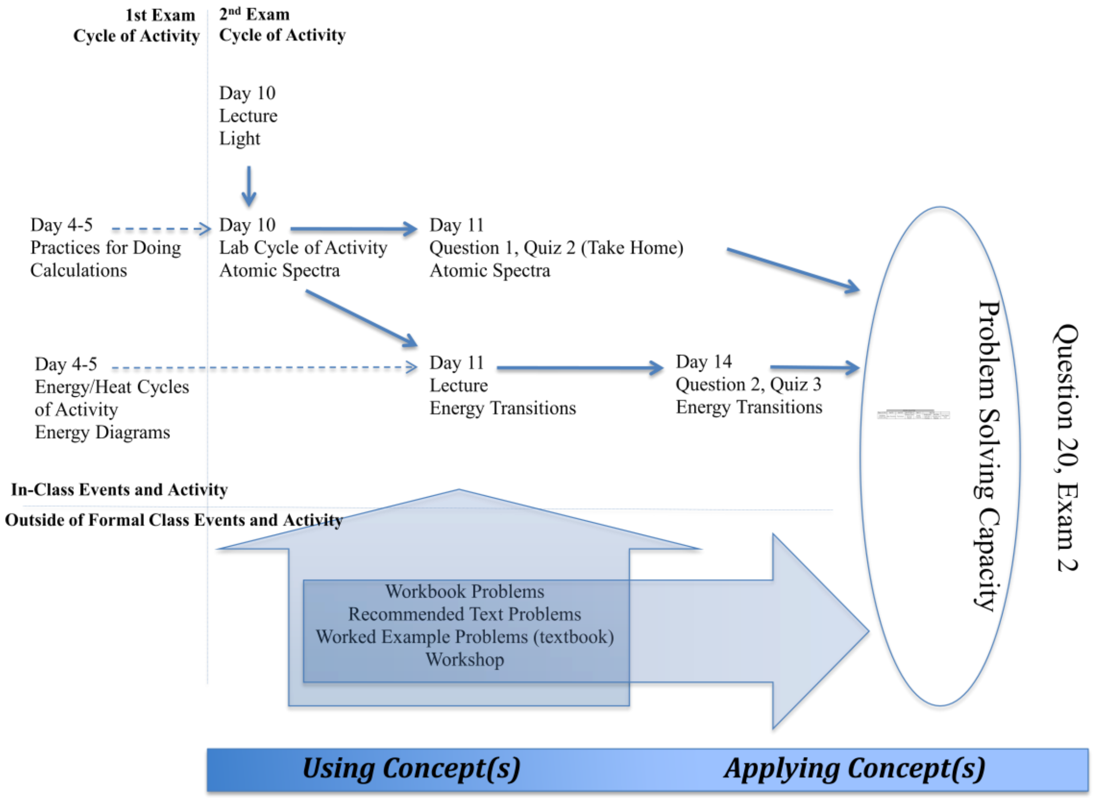


Figure 34. Summary of opportunities inside and outside of formal class time that potentially contribute to constructing a student's problem solving capacity for use in doing Problem 2 of Exam 2. Solid arrows represent the trace in proposed disciplinary content. Dotted arrows link the origin of proposed practices with proposed disciplinary content on Days 10 and 11 that were required by students as material resources.

experience the functionality of the concept which is commensurate with the definition of the word *use*, "put into service". However, the process of *applying* concepts in a quiz or exam requires different demands of the student. In quizzes and exams, the student is required to interpret the question and then derive the appropriate concept that is, according to the definition of *applying*, "mak[ing] use of as relevant, suitable, or pertinent". Deriving the relevant, suitable, or pertinent concept from the situation proposed in the problem is *applying* a concept.

Figure 34 represents the potential resources upon which students could use to build the problem solving capacity (constructing resources) for this specific disciplinary content. This process began with learning how the concept was used. Students then had to gain enough familiarity with the uses of the concept (i.e., build enough problem solving capacity) in this content area to apply it in new contexts. The only opportunity for students to engage with this content in table and lab-partnered groups was in the atomic spectra lab. Therefore it was imperative that students also worked problems outside of class.

Summary of findings for Research Question 4. By anchoring the analysis in a select question on Exam 2, this section traced the initiating and using of practices required in constructing problem solving capacity of a select concept. Understanding and displaying content knowledge of the relationship between energy level transitions, wavelength, and energy, which are represented in Equations 1, 2 and 3 in this section, required that students take up and use proposed content from the first week of the course through and to the 2nd Exam in Week 6 (Figure 34). As such, the primary finding of this section is that developing problem solving capacity for a domain is a process of using the concepts of the domain over time and in various ways. This analysis suggests that a key feature of this process is transforming from *practices for using concepts* to *practices for applying concepts.* Students *used* the concepts in the lab cycle of activity on Day 10 since the concept was made available in the lecture on light and in the pre-lab lecture on atomic spectra prior to the lab on atomic spectra. However, in quizzes and exams, students must draw on their problem solving capacity in the domain to locate, reformulate, and *apply* the concept in a new or different context.

Thus far, I have analyzed the designing of instruction and the tracing of practices for problem solving for a select concept area within this course design constructed predominantly at the whole class (interactions between instructor and all students) as collective level of analysis. I have also claimed that building problem solving capacity includes moving from *using* a concept to *applying* a concept. As a continuation of this argument, I now adjust the focus of the analytical perspective, still within this content area, from whole class activity to actions and interactions of select lab-partnered groups within a select table group, in an exploratory analysis of how and in what ways students use or apply concepts in the same trace of content analyzed in this section.

Research Question 5. In what ways did students construct opportunities for learning how to use or apply concepts for the selected disciplinary content (in Question 4) within lab-partnered group and table interactional spaces?

Addressing this research question is approached in four parts. First, I explain the logic of selecting the atomic spectra lab as the space for analysis as well as the logic of selecting the table group for study. Second, I construct a flow diagram making visible how and in what ways the material resources were publically available to students on Day 10. Third, in a comparative analysis of two lab-partnered groups within the select table group, I make visible how and in what ways students use disciplinary content in atomic spectra lab in order to accomplish the instructor-intended outcome of this activity. Fourth, I conduct another comparative analysis of the interactions of the same two lab-partnered groups with other actors (largely a factor of the physical design of this studio) that mediate their processes of negotiating how to use disciplinary content in order to accomplish the goals of the lab activity.

Selection of the event for analysis. Within the trace of disciplinary content shown in Figure 34, I selected the lab cycle of activity for atomic spectra on Day 10 as the focus of this analysis for several reasons. First, from the student perspective, "applying" concepts usually occurred when students did lab. In a voluntary online survey (33 of 67 students participated) that asked students "What does it mean to you to 'apply concepts' with respect to your general chemistry class? In other words, what does 'applying concepts' look like?" the highest number of free-responses (25 of 33) included a reference to doing lab as counting as a space for applying a concept in this course (see Figure 35). Second, it was the only event where the opportunity for learning was based in the table and lab-group interactional spaces (see Figure 12, Event Map of Day 10) and the audio records of all four lab-partnered groups

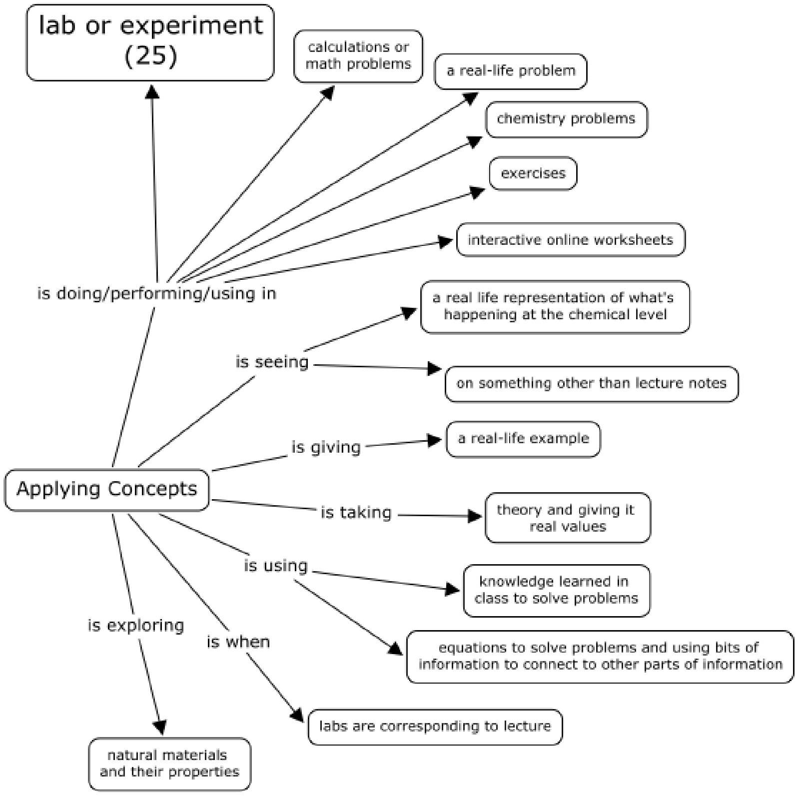


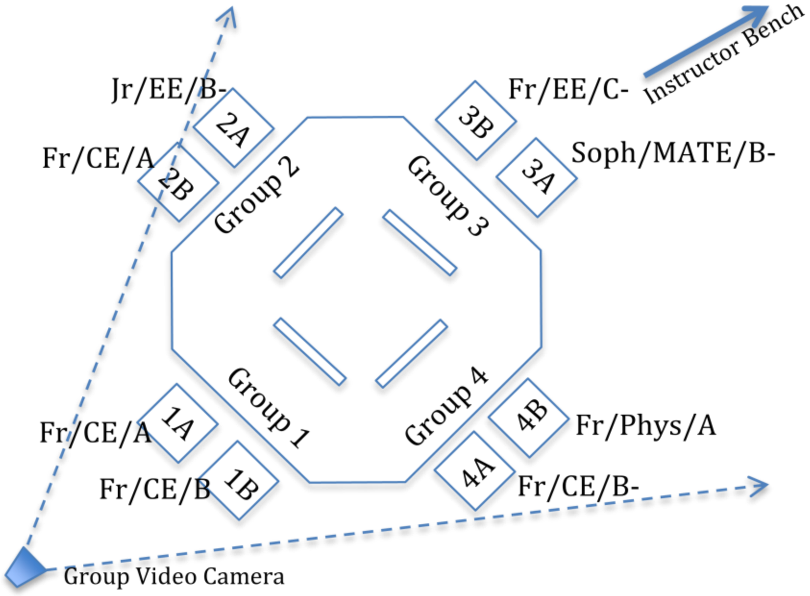
Figure 35. Taxonomic analysis of student survey free responses asking how students apply concepts in their General Chemistry class. The survey was administered in Weeks 8-9 of the course. Of the 67 students in the course, 33 responded to this question. Responses with no numerical value count as one student response.

volunteered their final lab reports for inclusion in the archive. In this way, available records for this particular lab event supported the constructing of data from the collective level to the lab-partner level of analysis.

Selection of table group. As explained in the methods chapter, the select table group of four lab-partnered groups was chosen for convenience. On the first day of class, the two video cameras were pre-positioned prior to the start of class on the first day in the back corner of one side of the classroom (see Appendix A). One camera focused on the instructor. The other was centered on the table group with a wired microphone positioned in the work area of Group 4. This camera and microphone configuration remained constant until the end of Week 3. At this time, three more stand-alone digital recorders were positioned in the workspace of the remaining lab-partnered groups (Groups 1-3). I pre-selected the table for study that was physically closest to my planned position in the room. Students self-selected their tables and seating positions (therefore, lab-partnered groups).

Demographics of the table group under study. Figure 36 shows the relevant student demographics by seating position for use in this study. Specifically, Figure 36 shows that this table group consisted of four freshmen civil engineering majors, positioned on half of the table. Remaining students were one junior electrical engineer, one freshman electrical engineer, one sophomore materials engineer and one physics freshman who later transferred (post-course) to mechanical engineering. Student final grades in the class are also annotated by student position. Grades ranged from A (three students) to C- (one student). All students at this table group were male. For convenience in identifying students and student groups at this table, each of four pairs are identified as Groups 1 to 4. Additionally, each student is identified with an A or B.

For the purposes of this study, Groups 1 and 3 were selected for comparative analysis because they represent disparate overall performance outcomes in the course.



Year Group /	Academic Major /	Final Grade in Chem124
Fr – Freshman	CE – Civil Engineering	A 90% - 100%
Soph – Sophomore	EE – Electrical Engineering	B+
Jr - Junior	MATE – Materials Engineering	B
	Phys - Physics	B-
		C+
		C
		C-
		D

Figure 36. Student seating positions with demographics of table group under study. Demographics are shown in a three code slant showing year group, academic major, and final grade in this course (Chem 124).

Group 1 students earned an A and B while Group 3 earned C- and B- grades. Final course grades may indicate students' ability to take up and display required disciplinary content knowledge and practices in this course. A summary of performance on assessments in this disciplinary content area that were available in the archive is shown in Table 27.

Table 27

Performance Outcome of Lab-Partner Groups 1 and 3 in Table Group Under Study

Student Identifier Grp/Psn	Atomic Spectra Lab	#2, Quiz 2	#20, Exam 2	Final Grade
1A	100%	87%	100%	A
1B	100%	87%	90%	B
3A	89%	93%	70%	B-
3B	83%	50%	0%	C-

Resources available to students for lab (Atomic Spectra) on Day 10. To make visible the resources available to students on Day 10, Figure 37 shows the flow of activity on this day with annotations showing references to content that was introduced prior or foregrounding content that would be proposed later. The solid boxes linked by solid arrows represent actions taken by participants for constructing this class day. The split between lecture and lab cycles of activity is annotated. Dashed arrows that return to prior actions represent requirements to use these as resources for current work or as foregrounding for future action. The block annotated as "administrative" is a proposal by the instructor to students that they should remain in class to see her demonstrate a sample calculation.

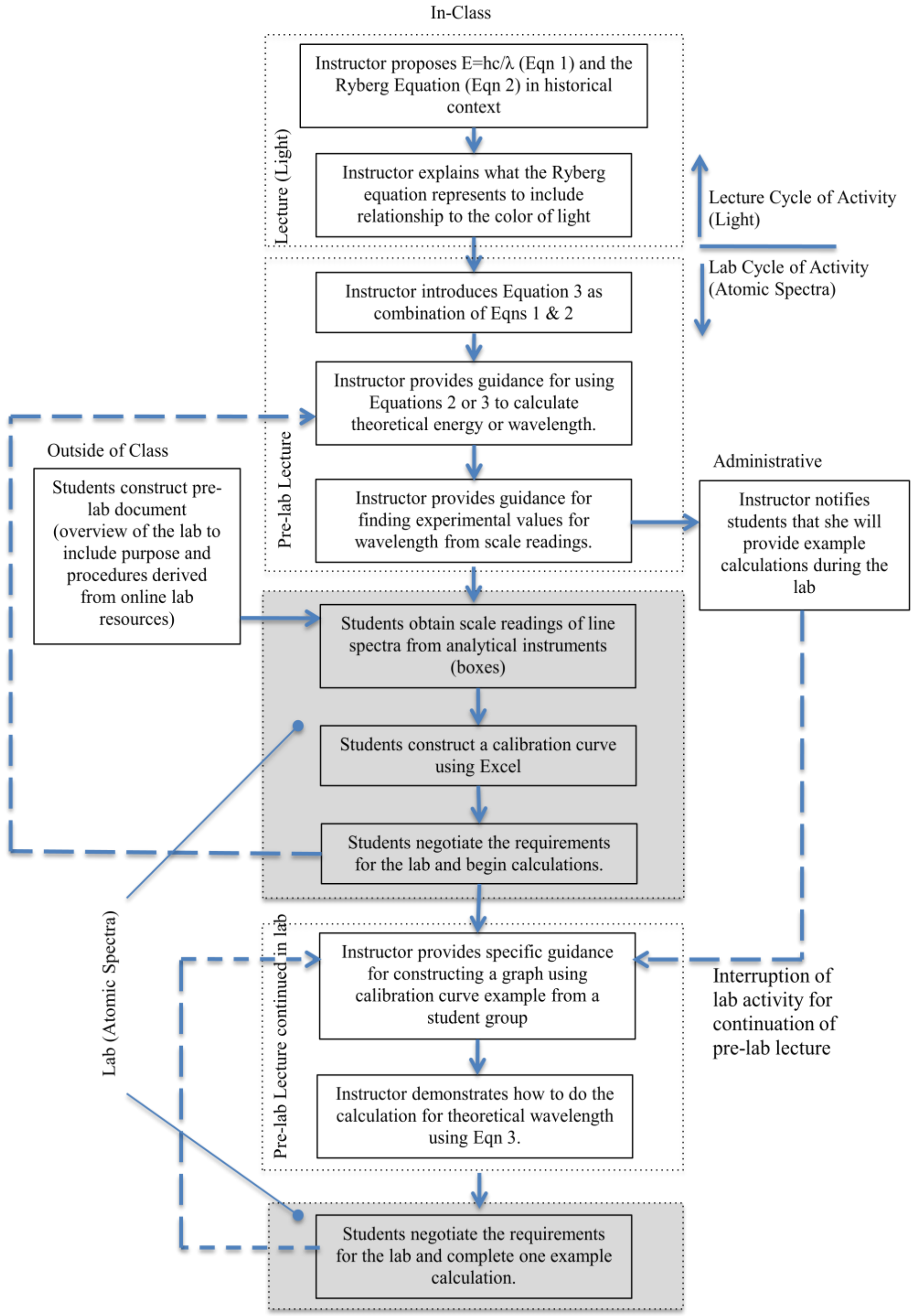


Figure 37. Flow diagram showing the resources available to students on Day 10. Shaded areas show activity occurring in lab-partner and table group interactional spaces.

Figure 37 shows that content required for students to do the atomic spectra lab came from three main sources. First, the disciplinary content, mainly in the form of Equations 1 and 2, was introduced in a historical context in the lecture cycle of activity just prior to the lab cycle of activity on the same day, Day 10. Second, in preparation for doing the lab, students were required to submit a written "pre-lab" to be checked by TAs at the beginning of the lab. Like previous pre-labs, this pre-lab consisted of a summary of the procedures and outline of required data tables that students were required to deduce from lab online resources. Third, according to Figure 37, the pre-lab lecture consisted of the instructor guiding students in a lecturing activity about how the major lab components fit together conceptually. The continuation of the pre-lab lecture provided a sample calculation and re-telling of how the components fit together conceptually.

Comparative analysis of lab-partnered groups co-constructing the Atomic Spectra Lab. Figure 38 shows how Groups 1 and 3 spent time during the atomic spectra lab. This figure was constructed as a representation of phases of activity from an observation table for each of Groups 1 and 3. These were based in activity determined from group interactions as students worked cooperatively to accomplish the requirements for doing the in-class portion of the lab.

For convenience in this analysis, time is set at 0 at the beginning of the lab event within the lab cycle of activity. Time spent on each activity for Group 1 is shown on the left side of the figure. Group 3 activity is shown on the right side. Group 1 spent 80 minutes in the lab activity while Group 3 spent 65 minutes. Note

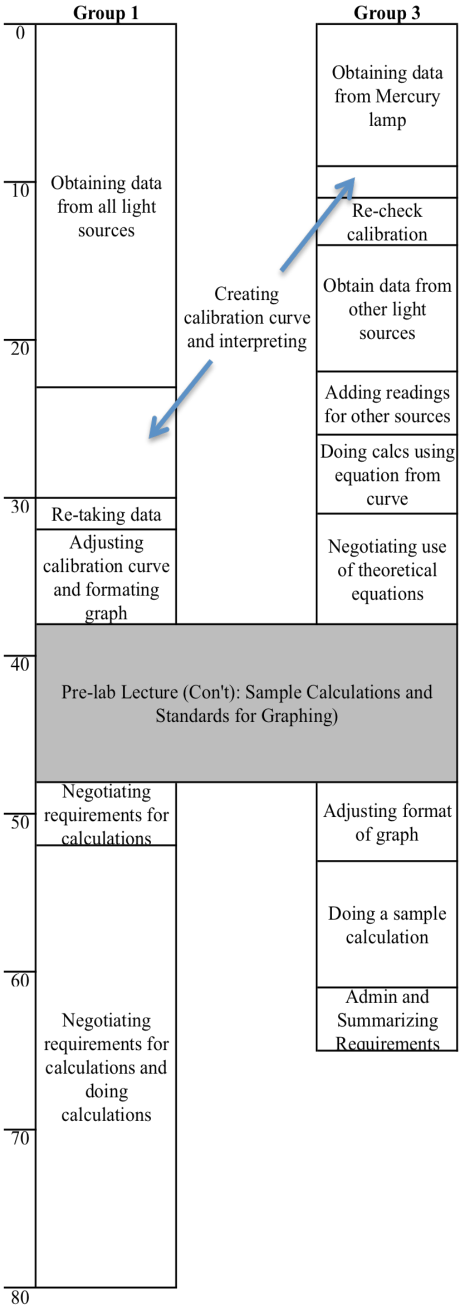


Figure 38. How time was spent for Groups 1 and 3 during the atomic spectra lab on Day 10.

that from minutes 38 to 48 in the lab event, the instructor reoriented the class as a collective for a planned continuation of the pre-lab lecture where she demonstrated a sample calculation and explained standards for displaying a graphical representation (Figure 17). Also during this lecturing activity, the instructor recommended that students do at least one calculation for wavelength before they departed the class.

Both Group 1 (the A/B group) and Group 3 (the C-/B- group) completed the requirement of the lab to obtain data. However, it seems from Figure 38 that Group 3 outperformed Group 1. Group 3 finalized a calibration curve and began negotiating how to calculate theoretical wavelengths well ahead of Group 1. When Group 3 was departing the classroom, Group 1 was still negotiating the data requirements.

Despite these differences in the timeline for accomplishing the goals of the in-class portion of the lab, Figures 39 and 40 make visible an alternative perspective on what was happening in these two groups in the lab activity. Figures 39 and 40 show the same representation of how time was spent for Group 3 and Group 1, respectively, that was shown in Figure 36. However, it also includes another layer of data. Nearest neighbor groups, Groups 2 and 4 flanking the center columns representing Groups 1 or 3 reflect the groups' physical positionings around the table. Interactions of Groups 1 and 3 with other actors is annotated by a solid line arrow pointing in the direction of the question. In these figures, nearest neighbor groups are shown explicitly because they are the most likely to interact with Groups 1 and 3 due to group orientation around the table and proximity between groups. Group 1 is on the other side of the table not easily accessible to Group 3 because of increased distance

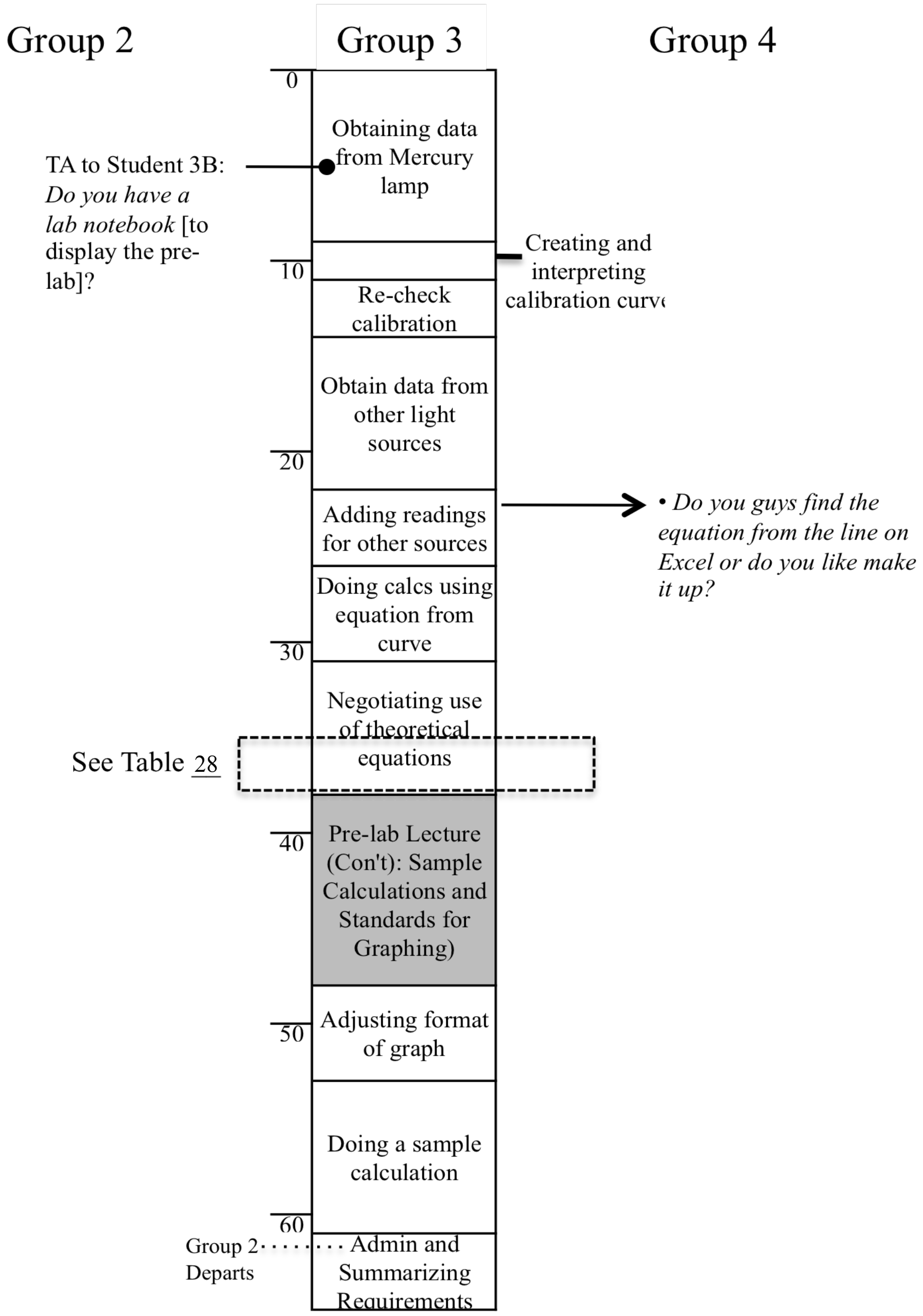


Figure 39. Documented interactions between Group 3 (C-/B- Group) and other actors during the atomic spectra lab on Day 10.

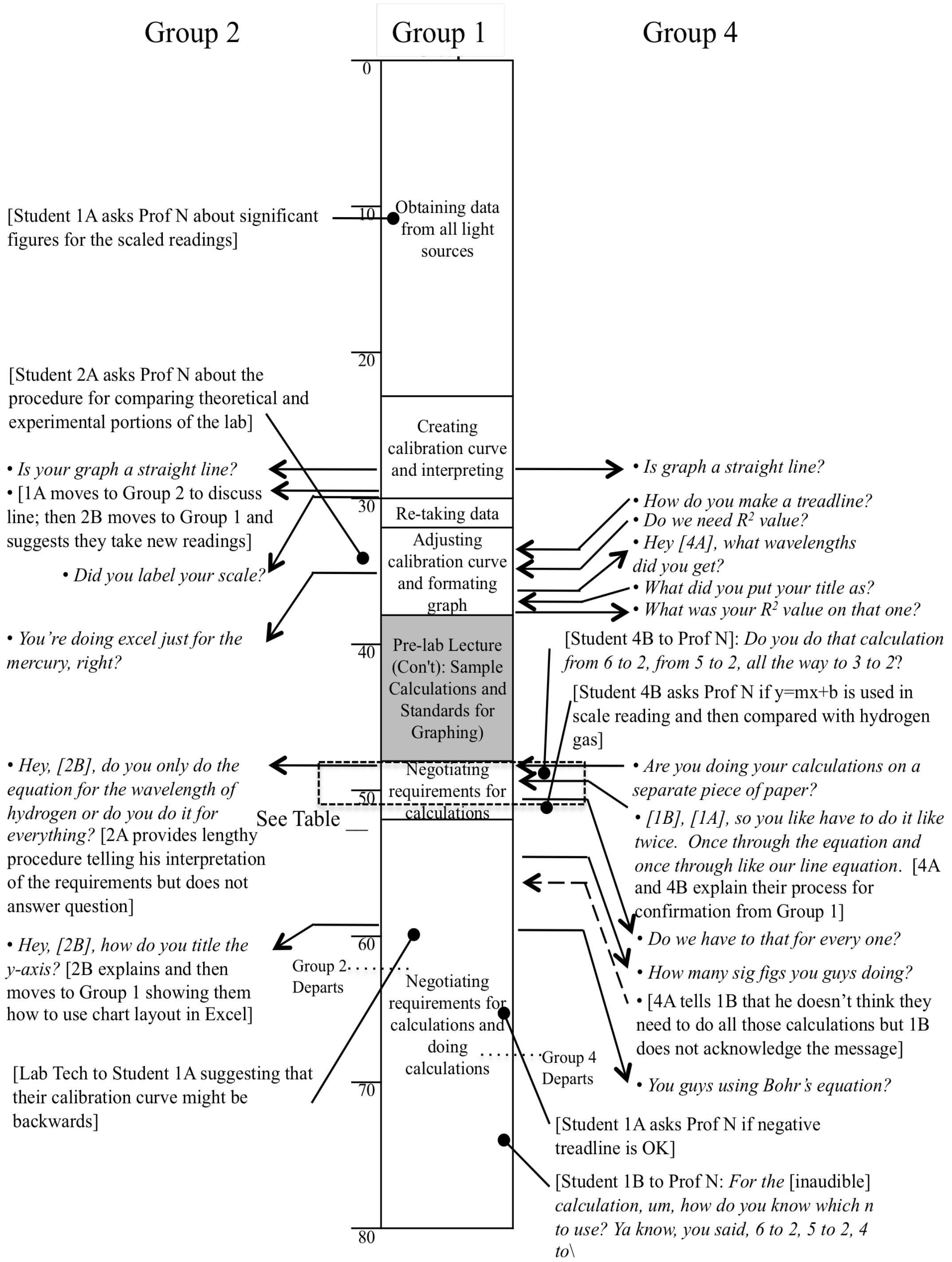


Figure 40. Documented interactions between Group 1 (A/B Group) and other actors during the atomic spectra lab on Day 10.

and the computer monitors partially obstructing line of sight and sound. For example, in Figure 39, arrows going from Group 3 towards Group 4 mean that Group 3 initiated an interaction with Group 4 with the posed question shown. Figure 39 shows that Group 3 participated in only one interaction with another student group. There was also one interaction with a TA at 5 minutes annotated by a non-arrow line.

The same type of representation is shown in Figure 40 for Group 1 making visible the stark contrast in opportunities that the two groups have afforded themselves in accessing other groups within their table as resources for the lab activity. Although Group 1 initiates interaction with both Groups 2 and 4, direction of arrows signifies that Group 4 initiates interaction with Group 1 just as much. However, Group 2 does not initiate interaction with Group 1.

In order to examine how Groups 1 and 3 were either using or applying the concepts salient for this lab activity, select video and audio records from both group were identified for further analysis of the discourse. These selections are identified in Figures 39 and 40 by a dotted boxes. These areas were selected because they were key areas where these groups negotiated the requirements for the lab in terms of the experimental procedure and theoretical concepts. For visual ease, these transcripts (Tables 27 and 28) have been represented as tables to include the space for discourse from potential actors in Groups 2 and 4. Message units are identified by downward slants (\) or upward slants (/). The upward slant (/) also indicates increased intonation indicative of a question.

Discourse analysis for Group 3 (C-/B- Group) transcript selection. Table 27 shows the transcript representation of the discourse beginning at approximately 30 minutes into the lab (Figure 39) and ending when the instructor reorients students for the continuation of the pre-lab lecture at 38 minutes. Specifically, at this point in the lab activity, Student 3A has finished doing calculations using the equation from the calibration curve and recognizes that the next step is to "use the Balmer-Ryberg equation" (Table 27, Lines 22-23) to calculate theoretical wavelengths. The remaining 8 minutes chronicles this group's negotiating the next steps in the procedure as dictated from the pre-lab as written by Student 3A until this interactional space is interrupted by the instructor.

The there are three features of the discourse made visible in the interactions of Group 3 in this section of transcript that characterize how students constructed this opportunity for learning how to use or apply disciplinary content. The first of these is the level of conceptual understanding. It is not surprising that the level would be very basic, since these concepts were proposed for the first time on the same day. Student 3A's elongated mispronunciation of Ryberg and question "didn't we talk about those guys today/"(Lines 29-30) suggests that, initially, the students did not know what the Ryberg (Equation 2) or Bohr (Equation 3) equations were and much less how these fit into the lab activity. In lines 38-43, Student 3B produced the Ryberg equation from his notes and the group attempted to negotiate the meaning of *n* (Lines 44-57). When neither suggested an answer, they moved on to the next procedural requirement (Lines 55-63). Their strict dependence on the written procedure (pre-lab) to get them

Table 28

Transcript of Group 3 Negotiating Required Calculations for the Atomic Spectra Lab

Line#	Time	2B	2A	3B	3A	4B	4A
1	0:11			[looking at monitor]	ok\ here’s what we got		
2	A29:54				so far\ [looking down at		
3					notes then back to monitor]		
4	2:17				thank you\ [returns		
5					calculator to Student 3B]		
6				yep\			
7	2:45				[silently reading from		
8	A32:30				notebook]		
9					[slowly reading from		
10					notebook] oh\ so\ use		
11					the balmer ryberg		
12					equation to calculate\		
13					theoretical wavelengths and [inaudible]		
14				you did that\ right/			
15					yeah\ you have the		
16					webpage up/ just go to		
17					the next one\ uh\		
18	3:19				wait a minute\ what was		
19					bohrs/ and\ uh\		
20				what/			
21				[looking at papers]			
22					we need to use Balmer\		
23					and Rayberg\ Ryberg		
24					equations\ [reading from notebook] [looking at papers]		
25	4:49			are we supposed to know\			
26				what level they are in/			
27					I think so\ but\		
28					uh\ I don’t know\		
29	5:04				and didn't we talk about		
30					those guys today/		
31				who/ about ryberg\	[looking through papers]		
32				[looking at monitor]			
33	5:46				there’s nothing under		
34					ryberg/ any equations/		
35				what/			
36					there are no equations		
37					under rybergs/		
38				ryberg/ it’s like right here\			

Line#	Time	2B	2A	3B	3A	4B	4A
39				[inaudible] one oh nine			
40				seven ten to the seventh			
41				meters\ and then\ one over			
42				n one squared minus one			
43				over n two squared\			
44				but I just don’t know\ which\			
45				she did tell us where			
46				helium was\ er\			
47				the helium\ she showed us			
48				the spectrum\ how purple			
49				was from\ 6 to 2\ then\ 5 to 2			
50	6:26				oh yeah\ the n equals 6\ k		
51				yeah\			
52					oh\		
53					do you know what that		
54					means/		
55	6:36			I know what it means\ I			
56	A36:25			just don’t know which			
57				one\ is which\			
58	7:22			so what are we supposed			
59	A37:04			to be doing next/ like what			
60				was next on the			
61					[reading from notebook]		
62					oh\ like\ ok\ so\ blah		
63					blah blah\ for colors and		
64					graph numbers use		
65					equation\ find		
66					wavelengths for these		
67					lines\ use balmer		
68					equation\ ryberg		
69					equation to calculate		
70					theoretical wavelengths		
71					and energies for photons		
72					emitted\ and look-up the		
73					gas emission tube\ oh		
74					and then\ we\ compare\ I don’t know\ we need the\ the balmer and ryberg\ so\		
75	8:05			[Interruption of Table and Lab-Partner interactional			
76	A37:47			space by instructor for continuation of pre-lab lecture]			

through the in-class requirements to obtain data (Lines 9-13, 58-59) is further evidence that concepts were not driving this exploration. So this section of transcript makes visible how this group of students began to first develop and talk about, in this case, the representation of a concept. However, their practices for addressing the concepts may have limited their opportunities for learning more so than the unfamiliarity with the content itself.

The second feature made visible in this transcript focuses on the social aspect of the students' problem solving practices: Each member of Group 3 negotiated problem solving largely independently of his partner. In negotiating how to do the required calculations, Student 3A read from his pre-lab that they needed to use the Ryberg equation to calculate theoretical wavelengths (Table 28, Lines 10-13) and eventually found the equation with the help of Student 3B (Table 28, Lines 10-43). However, when Student 3A asked Student 3B, "do you know what that [*n* in the Ryberg equation] means" (Table 28, Lines 53-54), Student 3B responded, "I know what it means\ I just don't know which one\ is which\" (Table 28, Lines 55-57). Clearly, from Student 3A's references to "didn't we talk about those guys today" (Table 28, Lines 29-30) and "the *n* equals 6" (Line 50), he was asking an authentic question and looking for a response for what the variable *n* means. By not acknowledging Student 3A's authentic question and redirecting the topic, Student 3B signaled to Student 3A that his question was insignificant or not important to Student 3B. After 45 seconds of silence and without reconciling how to *use* the Ryberg equation, Student 3B asked 3A what the next step was in the lab procedure (Table 28, Lines 58-60). Lines 22-23 and 72-74 show that Student 3A recognized that he needed this representation. However, when his attempt at using his lab-partner as a resource for understanding the variables in the equation was not acknowledged, this became a missed opportunity, an obstacle in the developmental process of learning how to use the Ryberg equation. By not soliciting help from their peers and by not addressing opportunities within their own group to resolve their own questions, Group 3 effectively isolated themselves as a group and to some extent they acted as isolated individuals trying to interpret and use the required equations.

Specifically, Student 3B repeatedly shows concern only for meeting the requirements of the lab activity to obtain the data. Furthermore, exclusively controlling the computer and the data represented in the graph and tables enabled him to also control the direction and pace of the lab namely by asking "so what are we supposed to do next/" (Lines 58-59). This directs the burden for negotiating the relationship between the conceptual and procedural requirements of the lab on Student 3A. This is also a pattern repeated outside of this transcript selection when Student 3B asked his partner "alright\ what else do we need to do/" and "is that what we need to do for the rest of the equations/" for example.

Group 3 departed the classroom with the data required. Student 3A also completed one calculation. However, it is not clear whether he compared theoretical and experimental values since he did not talk about this with his lab partner. Student 3B attempted a calculation but it is not clear if he completed it. The students did not compare their answers.

Discourse Analysis for Group 1 Transcript Selection. Interactions of Group 1 as they negotiated the required calculations look very different from Group 3 as evidenced by a section of transcript identified in Figure 40 by the dotted lined area and shown in full in Table 29. The transcript for Group 1 (Table 29) is represented in a slightly different way than the transcript for Group 3 (Table 28) because of the increased complexity of including discourse from other lab-partnered groups resulting in multiple interactional spaces, some occurring simultaneously. Interactional spaces are delineated with dotted lines that make boxes inclusive of the actor and times that they accessed a space. Shaded areas are spaces where neither member of Group 1 accessed. This section begins immediately following the continuation of the pre-lab lecture at 48 minutes into the lab activity and lasts for almost four minutes.

The salient features about the interactions of Group 1 are two-fold. First, their interactions with Groups 2 and 4 afforded opportunities to not only address their own question(s) but also afforded opportunities to confirm their own understandings and calculations. After not resolving his question with his lab-partner (Lines 100-102), Student 1A asked Group 2 whether they used "the equation" for hydrogen or "for everything" (Lines 103-110). Here, it is not clear which equation Student 1A is referring to and "everything" are the other elements available (helium, argon, and neon). As a response to the question, Student 2A summarized how the parts of the lab fit together with respect to the procedure. This utterance (Lines 111-128) shows Student 2A reformulating these ideas just after the instructor had proposed them. Student 1A responded half way through the explanation in the affirmative "right" (Line 124) that he agreed with the Student 2A's conceptualization of what to do in the lab. However, as recognized by Student 2B when he asked, "and do we do that for

Table 29

Transcript of Group 1 Negotiating Required Calculations for Atomic Spectra Lab

Line#	Time	2A	2B	1A	1B	4A	4B
100	17:33			how many times			
101				do you do it/			
102					I don't know\		
103				[to 2B]: hey (name			
104				of 2B)\ do you			
105	17:42		[reorients on 1A]	only do the\ use			
106				like the equation			
107				for the wavelength			
108				of hydrogen/ or do			
109				you do it for like			
110				everything\			
111	17:56	[reorients on 1A]:	[reorients on 1B]			[to 1B]: are you	[talking to
112		for the best fit line\				doing your	instructor at
113		ok\ I think it says				calculations on a	instructor bench]:
114		you plug in\ the				separate piece of	do you do that
115		position values for				paper/ or	calculation from 6
116		hydrogen\ into the\					to 2\ from 5 to 2\
117		um\ mercury					all the way to 3 to
118		equation\ in the					2/
119		best fit line\ you					[instructor
120		can get like\					responds yes]
121	17:57	expected value for			[reorients on 4A]		
122		your wavelength\			[inaudible]	[reorients on own	
123		and then you use			[reorients on own	work]	
		the calculation\ to			work]		
124	18:06	find new values for		right			[returns to seat, to
125		your wavelengths\					4A]: 6 to 2\ 5 to 2\
126		and you compare				[inaudible]	3 to 2 and 4 to 2
127		them\ and they're					[inaudible]

Line#	Time	2A	2B	1A	1B	4A	4B
128	18:12	not suppose to be				[to 4B]: we don’t	[to 4A]: do we
129		equal [talk ends at				need to turn this	need this/
		18:20]				in\	
130	18:16						[to 4A]: don’t we
131							like\ use this
132							equation for
133							something/
134							[pointing to
							monitor]
135	18:18					that’s what I don’t	
136	18:20	[talk ends here]	[to 1A]: and we do			get [looks towards	
137			that for all of			Group 1]	
138			them/ or just for			I think you have to	
139			[inaudible]			do it for both	
140	18:22	I don’t know if you		[reorients on his			both/
141		do that for all of		own paper in front		yeah\ [inaudible]	
142		them		of him]		to compare our\	
143						you know\	
144						[inaudible]	ok\ so\ let’s start
145	18:31					[to 4B]: wait a	
146						minute	
147	18:32					[reorient to Group	
148					[reorients on	1]: (name of 1B,	
149				[reorients on	Group 4]	name of 1A) so do	
150				Group 4]		you have to do it	
151						like\ twice/ like	
152						once through the	
153						equation\ and once	
154						through like our	
155						[gesturing to	
156						monitor] line	
157						equation/ and then	
158						once through\ like\	
						the real equation/	

Line#	Time	2A	2B	1A	1B	4A	4B
159	18:53			through the Neils\			
160				through the Bohr			
161				whatever\ Ryberg			
162						yeah	
163						you go once	
164						through the Bohr	
165						and then once	
166						through this [pointing at monitor]	
167							through the line
168							equation/ like do
169							you just plug in for
170							your x/
171					what’s x\		
172							um\ your scale
173							reading\ uh\ into
174							your y=mx+b
175							equation/
176							[gesturing to
177							monitor] and that
178							gives you the wavelength/
179					yeah [looking		
180					towards 1A and		
181					back to 4B] we		
182					have to do that for every one/		
183							I think so\ for each
184							color for each gas
185				sorry\ that's so			
186				many calculations\			

Line#	Time	2A	2B	1A	1B	4A	4B
187					I'll just stop		
188					showing [inaudible]		
189	19:55				which one did I		
190					just do/ hydrogen/		
191	20:40			what did you put/	[looking at shared notebook]		
192				[looking at shared			[4B talks with
193				notebook]			instructor]
194							[4A looking at 4B
195							with instructor]
196	21:15				[inaudible]		[4A to 1B]: I think
197					[no observable		we do it just for
198					response to 4A]		hydrogen

them all/" (Line 136-138), Student 1A's question had not been addressed in the response. Still, in this exchange, Student 1A confirmed his own understanding of what to do in the lab activity.

A similar situation also occurred in the interactional space occupied by Groups 1 and 4 starting at Line 147. This time, Group 4 initiates an interaction that begins as a question (Lines 147-158). As shown in Table 29, when Student 1A clarified the reference to the "real equation" (Line 158) as "through the Neils/ through the Bohr" (Lines 159-160), Student 4A continued explaining his conceptualization of the requirements (Lines 162-178) with declarative and clarifying statements. Student 1B then signaled agreement with 4A's explanations (Line 179) and redirected the conversation with the same question that 1A posed to Group 2 earlier, "we have to do that for every one/ [elements]" (Lines 181-182). The last portion of this sequence unit is the response from Student 4B, "I think so\ for each color of gas\" (Lines 183-184).

Although the outcome of this sequence unit led Group 1 to do unnecessary calculations for elements other than hydrogen which Group 1 did not resolve until minute 66, their interactions with Group 4 afforded them the opportunity to reformulate the logic of the lab procedure again. How the equation (explanatory representation for atomic spectra) manifests in the lab procedure is how the equation is *used*. So by doing the given procedure and by creating opportunities to publically explain what they are doing, students *are developing practices for using* the equation.

They are also inviting Group 1 to question them (Line 171). In this process, Groups 1 and 4 are developing a shared discourse for using this content.

Comparative analysis of negotiating the meaning of "n". As additional evidence of the disparity of social practices and resources accessed by Groups 1 and 3

Table 30

Select Transcripts of Groups 1 and 3 Negotiating the Meaning of "n" in the Atomic Spectra Lab

Student 3B	Student 3A	Student 1A	Student 1B
Ryberg/ it's like right here [inaudible] *one oh nine\\ seven\\ ten \\one over n\\ one squared minus one\\ over n two squared\\ but I just don't know\\ which\\ she did tell us where helium was\\ er\\ the helium\\ she showed us the spectrum\\ how purple was from\\ 6 to 2\\ then\\ 5 to 2*		*are you going to do those* *right now/* *the calculations/*	
			um\\ I just want to learn how to do one\\ then I'll be good
		I don't get what level it goes to\\ I think I'm going to do office hours tomorrow	
			ok\\ so change of energy\\ what's h/ is it h r squared/ is that the formula/
	oh yeah\\ the n equals 6\\ k		
yeah		*no\\ it's n\\ one over n*	
	oh\\ do you know what that **[*n*]** ***means/***		*oh\\ it's n*
		n final\\ yeah\\ if you're using this one it's	
I know what that means\\ I just don't know which one\\ is which			*n final squared*
(45s)		*it's n final squared minus n inverse squared*	
so what are we supposed to be doing next/ like what was next on the [lab procedure]			***so what's n/*** *is that the one point this value/*
		no\\it's not\\ I really don't know	
			oh\\ I think you just guess\\ you match it with the one that's closest
		you want to ask [Prof N]*/*	
			yeah

in this lab activity, Table 30 shows how both groups negotiated the same disciplinary content, the meaning of *n*. The variable *n* represents the energy level occupied by electrons in an atom and is the independent variable in the Ryberg equation (Equation 2) which relates an energy level transition to wavelength. It is also the independent variable in the closely related Bohr's equation (Equation 3) which relates an energy level transition to energy. The transcripts show the discourse leading up to and through what to do about resolving this issue. Shaded portions of the transcript show how each group proposed the question about the meaning of *n* and what actions they took. Group 3, shown on the left in the table, did not take up negotiating the meaning at all. As discussed previously, Student 3B did not entertain his lab-partner's request for information. Rather, he redirected the issue to moving to the next procedural requirement.

In stark contrast, Group 1 negotiated the meanings of variables in the equations. At the point where they exhausted their understanding, Student 1A asked 1B if he would ask the professor for help. Student 1B complied amiably. Student 1A had initiated a question with the instructor previously in the lab so this exchange shows a balanced approach to their responsibility for resolving issues.

By the end of each group's time in the lab, both groups met the basic data requirements of the in-class lab activity; however, they accomplished these goals in significantly different ways. Group 3 did not seek help from other groups at their table or from the instructor or TAs for help. Group 1 used other groups, the lab tech, and the instructor as resources to negotiate their way through the lab requirements.

This made a difference in the opportunities for learning that Groups 1 and 3 afforded themselves in developing the practices for using this content. For Group 1, this included opportunities for learning that the Ryberg and Bohr equations can only be used for one electron systems such as hydrogen as well as developing the discourse as a resource for further discussion about these concepts.

Summary of Findings for Chapter V

The topic of problem solving, specifically with respect to using and applying concepts, manifested in Professor N's claim, with regards to students not performing well on a specific exam question, that "they [students] might understand the concepts in the context that I give it to them in, but they have a horrible time applying concepts to new different contexts" (Email correspondence, 15 Feb 2012). Beginning with how problem solving is proposed to students (Research Question 3), I traced how and participants constructed the opportunities for learning the problem solving practices required for a student to address a specific problem, Problem 20 on Exam 2 (Research Question 4). Then I made visible how students took up these problem solving practices in an exploratory analysis based in student discourse within table and lab-partner group interactional spaces.

The primary finding from Research Question 3 was that in course documentation and the instructor's initial guidance, problem solving was positioned in terms of what to do inside and outside of the class. Inside of class, students were told to engage with the content by working problems on their own and accessing other peers for help. Outside of class, they needed to "struggle" with problems every day and, cumulatively, 8 to 10 hours a week, to name a few. Also, course documentation identified "applying concepts" as one of the critical elements to problem solving but was less clear about what that meant.

In Research Question 4, the concepts and practices required to work the problem in Problem 20 of Exam 2 were identified and traced. Analysis of the practices required to work the problem showed that a correct solution included not only the correct domain knowledge but also required procedural knowledge of how to display the solution. The trace of atomic spectra concepts with the exception of energy diagrams, was limited to the quantum theory and atomic structure cycle of activity (Days 9-14), the first content cycle of activity in the second exam cycle of activity. However, the procedural knowledge, specifically how to do a calculation, was proposed in the first cycle of activity, mainly on Days 4 and 5, such that these were normalized ways of doing calculations-based problems in the second exam cycle of activity. All these analyses show domain and procedural knowledge as socially proposed and negotiated among instructor and students.

However, the critical finding to this discussion about problem solving with respect to "applying concepts" is that this term was used in all cases where a problem required solving regardless of the situational context of doing the problem. Specifically, instructor and student patterns of discourse did not differentiate between the instructor demonstrating how to do a problem where concepts were proposed *a priori* versus the student doing a decontextualized problem as part of a quiz or exam.

Analyses in Research Question 5 makes visible how students *used* concepts to negotiate the requirements for the atomic spectra lab. A comparison of two disparately performing lab-partner groups as the same table group showed that both groups met the requirements of the lab but were more focused on the procedural aspects of the atomic spectra lab rather than gaining conceptual understanding. Analysis of the discourse in both groups made visible the beginning of the process of students taking up domain knowledge as discourse by trying to appropriate the concepts (terms and equations) in negotiating the lab procedures. However, the two student lab groups accomplished the requirements of the lab in significantly different ways which made visible potential and differential consequences with respect to opportunities for learning disciplinary content (concepts and practices).

Chapter VI: Discussion, Implications, Limitations and Conclusions

Overview

Even though chemistry studios have been used in undergraduate institutions for nearly 20 years, they are still a novel learning environment in the chemical education community. Although the chemistry studio learning environment has been studied with respect to outcome performance measures, few studies have examined the affordances of studios, especially with respect to a critical element of any learning environment: the opportunities for learning problem solving practices.

Therefore, the purpose of this study was two-fold. One, I analytically described how this General Chemistry course functioned especially with respect to the innovative element of this environment, the physical design, where lecture and lab activity may be conducted in the same space and time. Two, I traced the opportunities for learning problem solving practices, namely by examining how participants co-constructed opportunities for using and applying concepts in class activity. This chapter includes a discussion of key findings, implications, limitations and a conclusion.

Discussion

This section locates key findings from both course structuring and problem solving analyses in terms of confirming and challenging evidence to current research and culturally normalized beliefs, as well as contributing new evidence to what is known about chemistry studio classrooms and applying concepts in problem solving.

What counts as lab and lecture. This study challenges the conception of what counts as lecture and lab in an undergraduate general chemistry course. In a traditional lecture classroom, students typically face a common front of the room and are oriented to the instructor as he or she writes notes and explains course content on an overhead projector or chalkboard. Some instructors may also choose to show pre-constructed slides and display on one wall of the classroom as students copy the notes. However, during a lecture in this studio classroom, students do not face a common direction. Rather, students are oriented to the computer monitors at their tables which display content from an instructor writing and explaining the information on a document camera.

A traditional laboratory is typically constructed for purposes of conducting experiments so the location is different than the lecture such that the lab and lecture may be different courses entirely. Traditional laboratory spaces consist of long tables or benches where lab partnered groups sit next to each other without facing one another. However, in a studio classroom, the lecture and lab can be conducted in the same space. In this studio classroom, partners have easier access to other partnered groups, since groups sit in circular tables. In a traditional laboratory, the instructor does not have the means to transition the whole class to a lecture function to explain a concept or show a calculation. In this studio, the instructor has the resources to transition the class from the lab event to a lecture event in order to propose disciplinary content immediately relevant in the lab and then transition back to the lab event. Within the lab function, the instructor has the flexibility to intervene with a lecture activity if needed.

Table group interactional space. There is also a unique social construct that emerges from the physical design of the studio classroom as it relates to the integration of lecture and lab functions: the table group as a collective interactional space. As shown in the data analysis, the table group as a collective interactional space affords students another resource to seek assistance during workbook problem events on ‘lecture’ days and during laboratory experiments. What is more, this collective interactional space, having consistent membership at each table group for the duration of the course, has the potential to develop its own cultural identity and relationships resembling those in science and engineering teams. With this in mind, opportunities for collaboration in the table group should be considered in the designing of opportunities for learning.

Lecture and lab cycles of activity. In light of how and in what ways lecture and lab manifests in this chemistry studio, this study also challenges the appropriateness of transferring a “lab and lecture” construct from the traditional chemistry lab and lecture course(s) into this innovative learning environment. Rather than designing instruction for one class period as strictly a “lab” or “lecture”, activity in this chemistry studio is based in the structuring of cycles of activity where the instructor proposes or contextualizes disciplinary content in a lecture or pre-lab lecture activity and then affords students opportunities to engage with the content either by working problems, doing an exercise, or by doing a laboratory experiment.

Because several of these cycles of activity can occur in one class period, the instructor in the studio classroom has the additional flexibility of designing lecture and lab cycles of activity on the same day.

Taken a step further, these cycles of activity can be conceptualized as a modular design. Within a modular design of instruction, instructors can begin to think about different ways of structuring modules that may use computer-based resources, such as modeling and simulations, available in these types of innovative classroom environments that are not typically available in the traditional lecture and lab settings (Johnson & Morris, 1999). Additionally, accessibility of table and lab-partnered group interactional spaces offers flexibility for designing shorter and more focused lab opportunities to potentially obfuscate the distinction between lecture and lab cycles of activity.

Differential opportunities for learning. This study confirms research showing that given the same task and collective resources, student groups will negotiate requirements differentially and largely based in the social practices that they have developed as a group (Kelly, Crawford, & Green, 2001). However, this study extends this finding to include lab group work at the undergraduate level. Despite the same social configuration of two lab-partnered groups (see Figure 36), Group 1 (A/B) and Group 3 (C-/B-), within the table group under study and the groups negotiating lab requirements in generally the same order of activity, Group 3 functioned entirely independent of the others. Even within their own group, the social practices of Group 3 stifled their own opportunities for learning disciplinary content by focusing exclusively on meeting procedural requirements rather than addressing content-based issues.

Differentiating between using and applying concepts. This study also shows that although the same term "apply" is appropriated in both example problems in lecturing activity and in problems on quizzes or exams, these situations place different demands on students. This difference is shown conceptually in Figure 41.

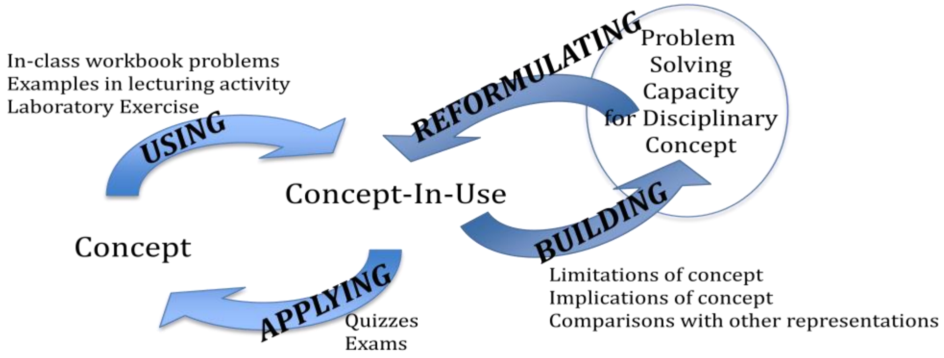


Figure 41. Representation of relationships between using, applying, building and reformulating in problem solving processes.

Figure 41 shows that the difference between using and applying a concept is in the origination and direction of moving between the concept and how it is used (concept-in-use). When students *use* a concept, it has been proposed by the instructor or some other resource and then put into use. In this way, the concept, usually represented in a mathematical equation in this course, is already available for students to then use. In other words, the proposed problem and concept are situated as the social context which is constructed in the interactions between instructor and students. However, in an exam or quiz, the concept is hidden within the parameters of the problem. Here, the problem is socially decontextualized and students must rely on their problem solving capacity in the domain to reformulate the parameters of the problem into the underlying concept. This is *applying* a concept. In order to apply a concept in a new context, a student must "know" the concept. Appropriating the term "apply" as a cover term for both *using* and *applying* obfuscates the different demands on students and is a missed opportunity to better describe the process of problem solving.

Lab-partner and table interactional spaces as a space for using concepts in discursive interactions. The exploratory analysis of undergraduate General Chemistry students negotiating the atomic spectra lab shows the same patterns of interaction that were shown in a study of 4th graders doing a computer-based physics lab (Roth, McGinn, & Bowen, 1996). Neither the undergraduates nor the 4th graders were applying concepts as I have defined this term. In both cases, students were trying to appropriate terms and relationships for what they were doing or trying to do in the lab activity. Roth (1996) described this as a process of students exercising interpretive flexibility, reconciling how to talk about a phenomenon and student experience with the phenomenon towards acceptable discursive forms for classroom talk.

Conceptualizing undergraduate lab activity in this way challenges beliefs about what students should be accomplishing in a lab activity, especially in studio learning environment. Students are not positioned towards the lab in the same way that they would be in a traditional lab where they were presumably introduced to the content days prior. In cycles of activity where students are introduced to the content an hour prior to a lab activity, students need time to develop the discourse required to negotiate the lab.

Implications

Implications for research field and instructors.

Implications for the research field and for instructors who want to be informed by research are closely interrelated and are, therefore, not separated.

Conceptualizing the designing of instruction. This study shows that the designing of instruction is an on-going process of participants co-constructing what it means to do, in this case, chemistry, rather than a set of structuring elements (i.e., lab, lecture). Researchers and instructors who want to be informed by this research need to conceptualize the designing of instruction as a process of flexibly applying a set of principles that guide how and in what ways this cultural group constructs what counts as doing class.

Conceptualizing problem solving as a social process. This study shows that the constructing of problem solving capacity is a social process where actors access cultural knowledge (disciplinary content) through interactions with material resources (people, cultural artifacts) over time. Implications for researchers and instructors who want to be informed by this research are that they must look beyond cognitive frameworks (individual mind as the unit of analysis) to study problem solving as originating as social phenomena. In this way, the potential for constructing problem solving capacity is limited by the resources publically available and shaped by the interactions between actors and artifacts.

Implications for practice. This study shows that within the formal class time, students were given opportunities to use concepts in doing workbook problems and in lab activity. Yet, students are often required to apply concepts in new or different contexts in quizzes and exams. Furthermore, the analysis suggests that being able to apply concepts in new or different contexts is socially significant for achieving success (getting a good grade) in this course. Because of the social significance of being able to apply concepts versus just using them, instructors should clearly distinguish between the terms "using" and "applying" concepts as characteristic of what is happening in class and how students should be engaging with content outside of class.

Within the opportunities for learning the select content area in this study (Chapter V), this analysis suggests that students must exercise their own agency in developing the problem solving capacity from "using" to "applying". Furthermore, in the case of this instructional design, the spaces for developing the practice of applying concepts is largely outside the classroom. Students must construct their own opportunities for learning how to apply concepts and be advised that this is a process of what the instructor proposed as "struggling" with the disciplinary content. In this way, the "struggling" first proposed by the instructor as behavior, can now be conceptualized as part of a developmental process where students initially use concepts to eventually apply concepts. In other words, "struggling" may be transformed in meaning from a behavior (no intent) to an action (intentional and goal-oriented). This is not to say that being able to do the problem is not a sufficient "goal". Rather this refers to a long term goal of moving from using to applying concepts. Clearly distinguishing between situations of using concepts and applying concepts is a critical part of this process.

Like the discussion about conceptualizing lecture and lab, distinguishing between using and applying concepts is not merely a (re)labeling of actions but an effort to influence how instructors and students *think* about what they are thinking and doing. In the same way that thinking about lab and lecture as cycles of activity may allow instructors to think about the designing of instruction in new ways, explicitly separating (the meaning of) *using* and *applying* concepts in speaking necessarily separates them in thinking (Vygotsky, 1986) and creates new possibilities for how instructors and students may describe these processes.

It is also important to recognize that this "struggling" to develop the language and models that describe scientific phenomena (Latour & Woolgar, 1986) is not just required of students in a classroom. After all, scientists and engineers do not spend time solving problems which have known solutions. From a sociocultural perspective, instructors, as cultural guides to the topology of disciplinary content, need to also include this aspect of the work as a normalized part of learning and doing chemistry (or any science or engineering discipline).

Considerations for a studio learning environment. This study also has implications for practice, specific to instructors new to a general chemistry studio. It is clear from this study and other literature (Bailey et al., 2000) that simply conceptualizing the “integrated lab and lecture” studio classroom as bringing traditional lab and lecture into the same time and space as traditional lecture and lab functions will be problematic because these are transformed within the chemistry studio. Keeping in mind that teachers tend to teach in the manner that they have been taught (Lortie, 1975), instructors need alternative models for designing opportunities for learning in their chemistry studio classrooms. But even with this support, instructors transitioning from a traditional model to the chemistry studio will inherently face cultural barriers to change.

A significant contributor to building and sustaining these barriers to change is the vocabulary that the science community uses to talk about what is happening in science classrooms. This study required particular attention to making visible what counted as "lab" and "lecture" in this context because of firmly rooted conceptions of what these words mean in the academic sphere of chemistry. Traditionally defined labels of "lab" and "lecture" do not just carry over vocabulary; they also carry over meaning. In this way, it becomes more difficult for instructors to become open to new ways of conceptualizing teaching and learning in innovative classroom environments within strongly held traditional frameworks of what counts as a "lecture" and a "lab". It is possible that in order to facilitate different ways of thinking about what happens in a chemistry studio, instructors need different ways of talking about it (new vocabulary).

Seeing alternative ways of teaching may not be enough to overcome barriers to change if instructors do not understand how the studio learning environment impacts their role of instructor. In thinking about how the collaborative interactional spaces in the chemistry studio can and should be used, instructors should consider also how and in what ways the chemistry studio impacts their role as instructor in comparison with the traditional conception of instructor as lecturer. To begin to experience the potential benefits afforded by the various collective interactional spaces requires instructors to handover some responsibility for learning (and teaching) to students, allowing students to create their own opportunities for learning as lab partners and table groups.

As shown in this study, handing over the responsibility for students to construct their own opportunities for learning means that these opportunities will not be the same for all students. Some student groups will develop social practices that foster a positive learning environment within their group. Some will not. This requires that the instructor consider ways to mitigate the risks to student opportunities for learning posed by ineffective student groups. This demands that the instructor learn to “read” student understanding in order to decide when, how, and under what conditions to intervene. Instructors may also explicitly describe how groups should work together and talk to each other with regards to negotiating problems, plan for interventions to reinforce the salient disciplinary content that student groups may be overlooking, or plan for periodic changes in student groupings.

Implications for administrators. This study also has implications for administrators who make "observations" of instructors in classrooms. The conceptual framework and methodology in this study implies that what an administrator "finds" during a classroom observation will be determined by their epistemological beliefs about how learning occurs and their presuppositions concerning what good instruction looks like. The position of this study is that to even begin to understand the processes and practices in structuring everyday life as well as constructing disciplinary knowledge requires observing actions and interactions of the group over enough time for patterns of activity to develop. Although administrators most likely do not have the time to rigorously and empirically study classroom life as demonstrated here, this study may provide situational awareness regarding an observer's limitations in being able to make evaluative assessments in one class period.

Implications for theory. As shown in this study, there is not one single theory that provides a conceptual base for understanding complex systems such as designing for instruction and problem solving as social processes. As a result, I took particular care in discussing how I constructed my orienting conceptual framework from various disciplinary traditions. Future work in understanding complex systems as social processes requires common ways of thinking about the phenomena. To this end, constructing a common conceptual framework would facilitate the development of the social nature of discourse in complex systems.

Implications for future research. The next step of this study should focus on further characterizing the science discourse within and between lab-partner groups and over time for discursive patterns that may better characterize using concepts versus applying concepts. Future research should also explore how different learning environments (including instructional designs) influence how students develop problem solving practices over time as evidenced by how students' science discourses change over time. In addition, this conceptual framework and methodology can be used to study other types of science-based studio classrooms for comparative analysis of cultural processes and practices with the intent of developing considerations for the designing of spaces for learning. Other practices as a focus of study could include designing investigations, interpreting data, and constructing evidence based arguments.

Limitations

This study was limited to mapping the collective interactional spaces and exploring problem solving practices in the first six of ten weeks of this general chemistry course for engineering majors in one class in one chemistry studio in two disciplinary content areas (thermochemistry and quantum theory and atomic structure). Furthermore, this study was focused on well-structured problems, specifically algorithmic and story problems, like those proposed on quizzes and exams rather than ill-structured problems that might be proposed in other types of instructional designs like problem-based learning (PBL). Within the conceptual framework of activities within the class as situated (Heap, 1991), clearly, these findings are not meant to be generalizable to other general chemistry classes, chemistry studios or problem types in a quantitative sense. Rather, this study offers ways to conceptualize collective activity in classroom environments and applying concepts in problem solving. The findings are useful for researchers and practitioners in so far as they see similarities or differences in their own research or situated classroom context.

Conclusion

This study makes visible how a studio learning environment affords students opportunities for using and applying disciplinary content within collective and group interactional spaces. Although these spaces provide opportunities for students to develop ways of talking and doing science, group social practices shape these opportunities differentially. This demands that instructors consider ways to help students construct effective interactional spaces for themselves as well as ways to recognize and mitigate ineffective group social practices. With respect to applying concepts, expecting students to apply content within problem solving in new contexts requires that instructors and students differentiate between the cognitive demands for using and applying concepts. Only then can participants begin to discuss the need for and characterizing of social practices for shaping the opportunities for learning in collective and group interactional spaces that would facilitate students moving from practices for using concepts to practices for applying concepts.

Glossary of Terms

Action - an act that one consciously wills that is observable as activity and implicates conscious intent [Definition is in contrast with "behavior"]

Activity - the general term for processes in action, usually in the form of a gerund

Apply(ing) - in the context of *applying* a concept in solving a problem, where a problem solver must deduce a concept and form of the concept and then use it in the process of solving a problem [Definition is in contrast with "using"]

Behavior - a psychological term for observable activity as a response to stimuli [Definition is contrasted with "action"]

Cycle of Activity - "...indicates a complete series of actions about a single topic or for a specific purpose" (Green & Meyer, 1991, p. 150). Used in this study as the major unit of analysis to distinguish between content and activity through the first exam (1st exam cycle of activity) and then content and activity after the first exam and through the second exam (2nd exam cycle of activity) for purposes of analysis.

Data - a representation of selected records constructed with a specific purpose or to answer a specific question. [Definition is in contrast with "records"]

Event - a culturally defined happening, bounded and characterized by purposeful activity or a chain of purposeful activity

Exercise - a condition of knowing how to get from one state to a desired state such that the process is routine, based in the relationship to the person providing a solution [Definition is in contrast with "problem"]

Ill-structured problems - problems where the problem parameters are unknown or may not be known to a high degree of certainty (Wood, 1983) with multiple solutions, solution paths, or no solution (Kitchner, 1983). Implicates problems that are also subject to personal values and moral judgments like those found in everyday life. [Definition is in contrast with "well-structured problems"]

Practice - specific skills performed habitually in and for a disciplinary content area; this includes ways of knowing, talking and doing in a disciplinary content area.

Problem - a condition of not knowing how to get from one (current) state to a desired state, based in the relationship to the person providing (or attempting to provide) a solution [Definition is in contrast with "exercise"]

Problem Solving - a complex process of resolving or attempting to resolve a problem.

Problem Solving Practices - domain specific practices (ways of knowing, talking and doing) used in the process of resolving or finding a solution to a problem

Records - video and audio representations of what could be seen or heard from a certain vantage point in the room, based in the positioning and technical capability of the instrumentation to record these representations; records also include collected cultural artifacts in text form (i.e., in-class worksheets, instructor notes, textbook, and assessments); records are equivalent to what the sciences may call "raw data". [Definition is in contrast with "data"]

Us(ing) - in the context of *using* a concept in solving a problem, where a problem solver has a priori knowledge of the concept or algorithmic form of the concept required to solve or move towards solving the problem [Definition is in contrast with "applying"]

Well-structured problems - problems that include the salient problem parameters or variables such that a single or set of objective solutions is attainable from a singular process path or limited set of process paths. Implicates problems that have an "approved solution". [Definition is in contrast with "ill-structured problems"]

References

Allaire, J. C., & Marskiske, M. (2002). Well-defined and ill-defined measures of everyday cognition: Relationship to older adults' intellectual ability and functional status. *Psychology and Aging*, *17*(1), 101-115.

Agar, M. (1995). *Language shock: Understanding the culture of conversation.* New York: William Morrow.

Agar, M. (2006). Culture: Can you take it anywhere? *International Journal of Qualitative Methods. 5*(2), Article xx. Retrieved Nov 20, 2011, from http://www.ualberta.ca/~iiqm/backissues/5_2/pdf/agar.pdf

Anderson-Levitt, K. M. (2006). Ethnography. In J. Green, G. Camilli & P. Ellmore (Eds.), *Handbook of Complementary Methods in Educational Research*, 279-295.

Apple, T., & Cutler, A. (1999). The Rensselaer studio general chemistry course. *Journal of Chemical Education*, *76*(4), 462-3.

Bahktin, M. M. (1986). *Speech genres and other late essays*. Austin, Texas: University of Texas Press.

Bailey, C. A., Kingsbury, K., Kulinowski, K., Paradis, J., & Schoonover, R. (2000). An integrated lecture-laboratory environment for general chemistry. *Journal of Chemical Education*, *77*(2), 195-9.

Baker, W. D., Green, J. L., & Skukauskaite, A. (2008). Video-enabled ethnographic research: A microethnographic perspective. In G. Walford (Ed.), *Ethnography* *and education: How to do educational ethnography*, (pp. 77-114), London: Tufnell Press.

Beichner, R., Saul, J., Allain, R., Deardorff, D., & Abbott, D. (2000). Introduction to SCALE-UP: Student-centered activities for large enrollment university physics. Report: ED459062. 13 Sponsored by Fund for the Improvement of Postsecondary Education (ED); Washington, D.C; Hewlett Packard Co., Cupertino, CA; National Science Foundation, Arlington, VA.

Bloome, D., Carter, S., Christian, B., Otto, S., & Shuart-Faris, N. (2010). *Discourse analysis and the study of classroom language and literacy events: A microethnographic perspective.* New York: Routledge.

Bodner, G., & Herron, D. (2002). Problem solving in chemistry. In J. K. Gilbert, et. al. (Eds.) *Chemical Education: Towards Research Based Practice*, pp. 235-266. Netherlands: Kluwer Academic Publishers.

Boshuizen, H. (2006). Teaching for expertise: Problem-based methods in medicine and other professional domains. In K. Ericsson (Ed.)., *Development of Professional Expertise: Toward Measurement of Expert Performance and Design of Optimal Learning Environments.* Cambridge: Cambridge University Press.

Brenner, M. (2006). Interviewing in educational research. In J. Green, G. Camilli & P. Elmore (Eds.), *Handbook of complementary methods in educational research*, (pp. 357-370). Mahwah, NJ: Erlbaum.

Bruffee, K. (1999). *Collaborative learning: Higher education, interdependence and the authority of knowledge.* 2nd Ed. Baltimore: Johns Hopkins University Press.

Bruner, J. (1985). Vygotsky: A historical and conceptual perspective. In J. Wertsh (ed.), *Culture, communication, and cognition: Vygotskian perspectives* (pp. 21-34). Cambridge: Cambridge University Press.

Castanehiera, M., Crawford, T., Dixon, C., & Green, J. (2001). Interactional ethnography: An approach to studying the social construction of literate practices. *Linguistics and Education*, *11*(4), 353-400.

Camacho, M., & Good, R. (1989). Problem-solving and chemical equilibrium: successful versus unsuccessful performance. *Journal of Research in Science Teaching*, *26*, 251-272.

Chi, M. T. H, Feltovich, P., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science*, *5*, 121-152.

Chi, M. T. H., Glaser, R., and Rees, E. (1982). Expertise in problem solving. In R. J. Sternberg (Ed.), *Advances in the psychology of human intelligence, Vol 1*. Hillsdale: NJ: Lawrence Erlbaum Associates.

Cummings, K., Marx, J., Thornton, R., & Kuhl, D. (1999). Evaluating innovation in studio physics. *American Journal of Physics*, *67*(S1), S38.

Edwards, D., & Mercer, N. (1987). *Common knowledge: The development of understanding in the classroom.* New York: Methuen.

Ericsson, K., Charness, N., Feltovich, P., & Hoffman, R. (2006). *The Cambridge handbook of expertise and expert performance*. Cambridge: Cambridge University Press.

Feltovich, P., Prietula, M., & Ericsson, K. (2006). Studies of expertise from psychological perspectives. In K. Ericsson, N. Charness, P. Feltovich, & R. Hoffman, R. (Eds.)., *The Cambridge Handbook of Expertise and Expert Performance* (pp. 41-67). Cambridge: Cambridge University Press.

Gee, J. P., & Green, J. (1998). Discourse, analysis, learning, and social practice. In P. D. Pearson (Ed.), *Review of Research in Education* (pp. 119-169). Washington, DC: American Educational Research Association.

Geertz, C. (1973). The Interpretation of Cultures. New York: Basic Books.

Geertz, C. (1983). Local Knowledge. New York: Basic Books

Gergen, K. J. (2009). *An invitation to social construction.* (2nd ed.). London: Sage Publications Ltd.

Gersick, C. J., & Hackman, J. R. (1990). Habitual routines in task-performing groups. *Organizational Behavior and Human Decision Processes*, *47*, 65-97.

Goodenough, W. H. (1981). *Culture, language and society.* 2nd Ed. Menlo Park, CA: Benjamin/Cummings Publishing Company, Inc.

Gottfried, A., Sweeder, R., Bartolin, J., Hessler, J., Reynolds, B., Stewart, I., Coppola, B., & Banaszak Holl, M. (2007). Design and implementation of a studio-based general chemistry course. *Journal of Chemical Education, 84*(2), 265-270.

Graetz, K., & Goliber, M. J. (2002). Designing collaborative learning places: psychological foundations and new frontiers. *New Directions for Teaching and Learning*, *92*, 13-22.

Green, J., Dixon, C., & Zaharlick, A. (2003). Ethnography as a logic of inquiry. In Flood, J., Lapp, D., Squire, J., & Jensen, J. (Eds.), *Research in the Teaching of the English Language Arts.* (pp. 201-224). Mahwan, N. J.: Lawrence Erlbaum Associates.

Green, J. L., & Meyer, L. A. (1991). The embeddedness of reading in classroom life: Reading as a situated process. In C.D. Baker & A. Luke (Eds.), *Towards a critical sociology of reading pedagogy: Papers of the XII World Congress on reading* (pp. 141-160). Amsterdam: John Benjamins.

Green, J., Shukauskaite, A., & Baker, W. (2012). Ethnography as epistemology. In Author, J.; Waring, M.; Coe, R.; Hedges, L. (Eds.), *Research Methodologies and Methodologies in Education.* (pp. 309-321). London: Sage Publications Ltd.

Green, J., Shukauskaite, A., Dixon, C., & Cordova, R. (2007). Epistemological issues in the analysis of video records: Interactional ethnography as a logic of inquiry. In R. Goldman, R. Pea, B. Barron & S. J. Denny (Eds.), *Video Research in the Learning Sciences* (pp. 115-132). Mahwah, NJ: Lawrence Erlbaum Associates.

Green, J., & Wallat, C. (1981). Mapping instructional conversations: A sociolinguistic ethnography. In J. L. Green & C. A. Wallat (Eds.), *Ethnography and language in educational settings* (pp. 161-205). Norwood, NJ: Ablex.

Gumperz, J. (1997). Communicative competence. In N. Coupland & A. Jaworski (Eds.), *Sociolinguistics: A reader and coursebook* (pp. 39-48). Basingstroke: Palgrave Macmillan.

Gumperz, J., & Berenz, N. (1993). Transcribing conversational exchanges. In J. Edwards & M. Lampert (Eds.), *Talking Data: Transcription and Coding in Discourse Research* (pp. 117-135). Hillsdale, NJ: Lawrence Erlbaum Associates.

Gumperz, J., & Cook-Gumperz, J. (2006). J. Interactional sociolinguistics in the study of schooling. In J. Cook-Gumperz (Ed.), *Social construction of literacy (2nd Ed)*. Cambridge University Press.

Gumperz, J., & Cook-Gumperz, J. (2008). Studying language, culture, and society: Sociolinguistics or linguistic anthropology? *Journal of Sociolinguistics 12*(4). 532-545.

Hayes, J. (1989). *The complete problem solver.* 2nd Ed. Hillsdale, N. J: L. Erlbaum Associates.

Heap, J. (1991). A situated perspective on what counts as reading. In C. Baker and A. Luke (Eds.), *Towards a critical sociology of reading pedagogy* (pp. 103-139). Philadelphia: John Benjamins.

Hegel, F. (1977). *The phenomenology of spirit*. New York: Oxford University Press.

Heras, A. (1994). The construction of understanding in a sixth-grade bilingual classroom. *Linguistics and Education, 5*, 275-299.

Heyworth, R. M. (1999). Procedural and conceptual knowledge of expert and novice students for the solving of a basic problem in chemistry. *International Journal* *of Science Education*, *21*, 195-211.

Hoellwarth, C., Moelter, R., & Knight, R. (2005). A direct comparison of conceptual learning and problem solving ability in traditional and studio style classrooms. *American Journal of Physics*, *73*(5), 459-462.

Hong, N. S., Jonassen, D. H., & McGee, S. (2003). Predictors of well-structured and ill-structured problem solving in an astronomy simulation. *Journal of Research in Science Teaching*, *40*(1), 6-33.

Huckin, T. (2004). Content analysis: What texts talk about. In C. Bazerman & P. Prior (Eds.), *What writing does and how it does it: An introduction to analyzing texts and textual practices.* Lawrence Erlbaum Associates, Inc., Mahwah: NJ.

Hymes, D. (1972). Toward ethnographies of communication: The analysis of communicative events. In P. P. Giglioli (Ed.), *Language and social context* (pp. 21-44).

Hymes, D. (1977). Critique. *Anthropology and Education Quarterly*, VIII(2), 91-93.

Johnson, J., & Morris, K. (1997). Courseware is the key: Bridging lecture and laboratory in general chemistry. *Journal of Computing in Higher Education*, *8*(2), p. 109-125.

Jonassen, D. H. (2012). *Learning to solve problems: A handbook for designing problem-solving learning environments.* New York, NY: Routledge.

Jonassen, D. H., & Kwon, H. I. (2001). Communication patterns in computer-mediated vs. face-to-face group problem solving. *Educational Technology:*

Research and Development, *49*(10), 35-52.

Kelly, G. J. (2008). Learning science: Discursive practices. In M. Martin-Jones, A. M. de Mejia and N. H. Hornberger (Eds.), *Encyclopedia of Language and Education* (2nd Ed.), Volume 3: Discourse and Education, 1-12. Springer.

Kelly, G. J., & Chen, C. (1999). The sound of music: constructing science as sociocultural practices through oral and written discourse. *Journal of Research in Science Teaching, 36* (8), 883-915.

Kelly, G. J., Crawford, T., & Green, J. (1997). Common task and uncommon knowledge: Dissenting voices in the discursive construction of physics across small laboratory groups. *Linguistics and Education*, *12*(2), 135-174.

Kirchner, K. S. (1983). Cognition, metacognition, and epistemic cognition: A three-level model of cognitive processing. *Human Development*, 26(4), 222-232.

Kumar, D. D. (1993). Assessment of expert-novice chemistry problem-solving using hypercard: Early findings. *Journal of Science Education Technology*, *2*, 481-485.

Larkin, J., McDermott, J., Simon, D. P., & Simon, H. A. (1980). Models of competence in solving physics problems. *Science*, 208, 1335-1342.

Latour, B., & Woolgar, S. (1986). *Laboratory life: The social construction of scientific facts.* Princeton, NJ: Princeton University Press.

Leach, J., & Scott, P. (2003). Individual and sociocultural views of learning in science education, *Science & Education*, *12*, 91-113.

Lee, K. L., & Fensham, P. (1996). General strategy for solving high school electrochemistry problems. *International Journal of Science Education, 18*, 543-555.

Lemke, J. L. (1990). *Talking science: Language, learning and values.* Norwood, NJ: Ablex.

Lemke, J. L. (1993). The missing context in science education: science. Paper presented at the Annual Meeting of the American Educational Research Association, Atlanta, GA. Retrieved from: http://academic.brooklyn.cuny.edu/education/jlemke/papers/gap-sci.htm on May 5, 2013.

Lortie, D. (1975). *Schoolteacher: A sociological study*. Chicago: University of Chicago Press.

Luria, A. R. (1976). *The making of mind: A personal account of soviet psychology*. Cambridge: Harvard University Press.

Malinowski, B. (1935). Coral gardens and their magic. London: Allen and Unwin.

Mehan, H. (1979). *Learning lessons: Social organization in the classroom.* Cambridge, MA: Harvard University Press.

Mitchell, J. (1984). Typicality and the case study. In R.F. Ellen (ed.) *Ethnographic research: A guide to general conduct* (pp. 238-241). NY: Academic Press.

Mishler, E. (1991). Representing discourse: The rhetoric of transcription. *Journal of Narrative and Life History*, *1*(4), 255-280.

National Research Council. (1996). From analysis to action: Undergraduate education in sci- ence, mathematics, engineering, and technology. Center for Science, Mathematics, and Engineering Education. Washington, DC: National Academy Press.

National Research Council. (1999). *Transforming undergraduate education in science, math- ematics, engineering, and technology*. Committee on Undergraduate Science Education, Center for Science, Mathematics, and Engineering Education. Washington, DC: National Academy Press.

National Research Council. (2002). Scientific research in education. Committee on Scientific Principles for Education Research, R.J. Shavelson and L. Towne, Eds. Washington, DC: The National Academies Press.

National Research Council. (2011). *Promising practices in undergraduate science, technology, engineering and mathematics education: Summary of two workshops.* Washington, D.C: The National Academies Press.

National Research Council. (2012a). *Discipline-based educational research: Understanding and improving learning in undergraduate science and engineering*. Washington, D.C: The National Academies Press.

National Research Council. (2012b). *A Framework for K-12 Science Education.* Washington, D.C: The National Academies Press.

National Science Foundation. (1996). *Shaping the future: New expectations for undergraduate education in science, mathematics, and technology.* Advisory Committee to the National Science Foundation, Directorate of Education and Human Resources. Arlington, VA: Author.

Neff, Grace. (2012). Web source: Dynamic Syllabus Winter 2012. http://chemweb.calpoly.edu/gneff/Chem124/Ch12409LectSchedW12.html

Newell, A., & Simon, H. A. (1972). *Human problem solving*. Englewood Cliffs, NJ: Prentice-Hall.

Nurrenburn, S., & Pickering, M. (1987). Concept Learning versus problem solving: Is there a difference? *Journal of Chemical Education, 64, 508-510.*

Patton, M. (2002). *Qualitative research and evaluation methods* (3rd ed.). Newbury Park, CA: Sage.

Pickering, M. (1990). Further studies on concept learning versus problem solving." *Journal of Chemical Education*, *67*, 254-255.

Posner, G. (2004). *Analyzing the curriculum.* New York: McGraw-Hill.

Random House Dictionary of the English Langauge, (2nd ed.). (1983). N.p: Random House.

Roehrig, G., Luft, J., Kurdziel, J., & Turner, J. (2003). Graduate teaching assistants and inquiry-based instruction: Implications for graduate teaching assistant training. *Journal of Chemical Education*, *80*(10), 1206-1210.

Roth, W.-M. (1996). The co-evolution of situated knowledge and physics knowing. *Journal of Science Education and Technology*, *5*(3), 171-191.

Roth, W.-M. (2005). *Talking science: Language and learning in science classroom*. Oxford: Rowman & Littlefield.

Roth, W.-M. (2010). Roth, W.-M. (2010a). ReUniting sociological and psychological perspectives in/for science education: An introduction. In W.-M. Roth (ed.)

Re/Structuring Science Education: ReUniting Sociological and Psychological Perspectives. Netherlands: Springer.

Roth, W.-M., McGinn, M. K., & Bowen, G. M. (1996). Applications of science and technology studies: Effecting change in science education. *Science, Technology, & Human Values*, *21*, 454–484.

Roth, W.-M., McGinn, M. K., Woszczyna, C., & Boutonne, S. (1999). Differential participation during science conversations: The interaction of focal artifacts, social configurations, and physical arrangements. *The Journal of the Learning Sciences*, *8*(3&4), 293-347.

Roth, W.-M., & Wetzel, M. (2001). From activity to gestures and scientific language. *Journal of Research in Science Teaching, 38*(1), 103-136.

Saul, J., Deardoff, D.L., Allain, R. J., & Beicher, R. J. (2000). Evaluating introductory physics classes in light of the ABET criteria: An example from the SCALE-UP project. In Annual Meeting of the American Association for Engineering Education (St. Louis, Missouri, 2000)

Sawrey, B. A. (1990). Concept learning versus problem solving: Revisited”. *Journal of Chemical Education*, *67*, 253-254.

Selzer, J. (2004). Rhetorical analysis: Understanding how texts persuade readers. In C. Bazerman & P. Prior (Eds.), *What writing does and how it does it: An introduction to analyzing texts and textual practices.* Lawrence Erlbaum Associates, Inc., Mahwah: NJ.

Schultz, E. (2000). A chemistry course with a laboratory for non-science majors. *Journal of Chemical Education, 77*(8), 1001-1006.

Silberberg, M. (2009). *Chemistry: The molecular nature of matter and change.* (6th Ed.). Boston: McGraw-Hill.

Simon, H. A. (1978). Information processing theory of human problem solving. In D. Estes (Ed.), *Handbook of learning and cognitive process*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Spradley, J. (1979). *The ethnographic interview*. Fort Worth, TX: Harcourt Brace.

Spradley, J. (1980). *Participant observation.* New York: Holt, Rhinehart, and Winston.

Tro, N. (2011). *Chemistry: A molecular approach.* (Custom Edition for California Polytechnic State University, San Luis Obispo). Prentice Hall.

Tuyay, S., Jennings, L., & Dixon, C. (1995). Classroom discourse and opportunities to learn: An ethnographic study of knowledge construction in bilingual third-grade classroom. *Discourse Processes, 10*, 75-110.

Vygotsky, L. (1978). *Mind in society: The development of higher psychological processes*. Cambridge: Harvard University Press.

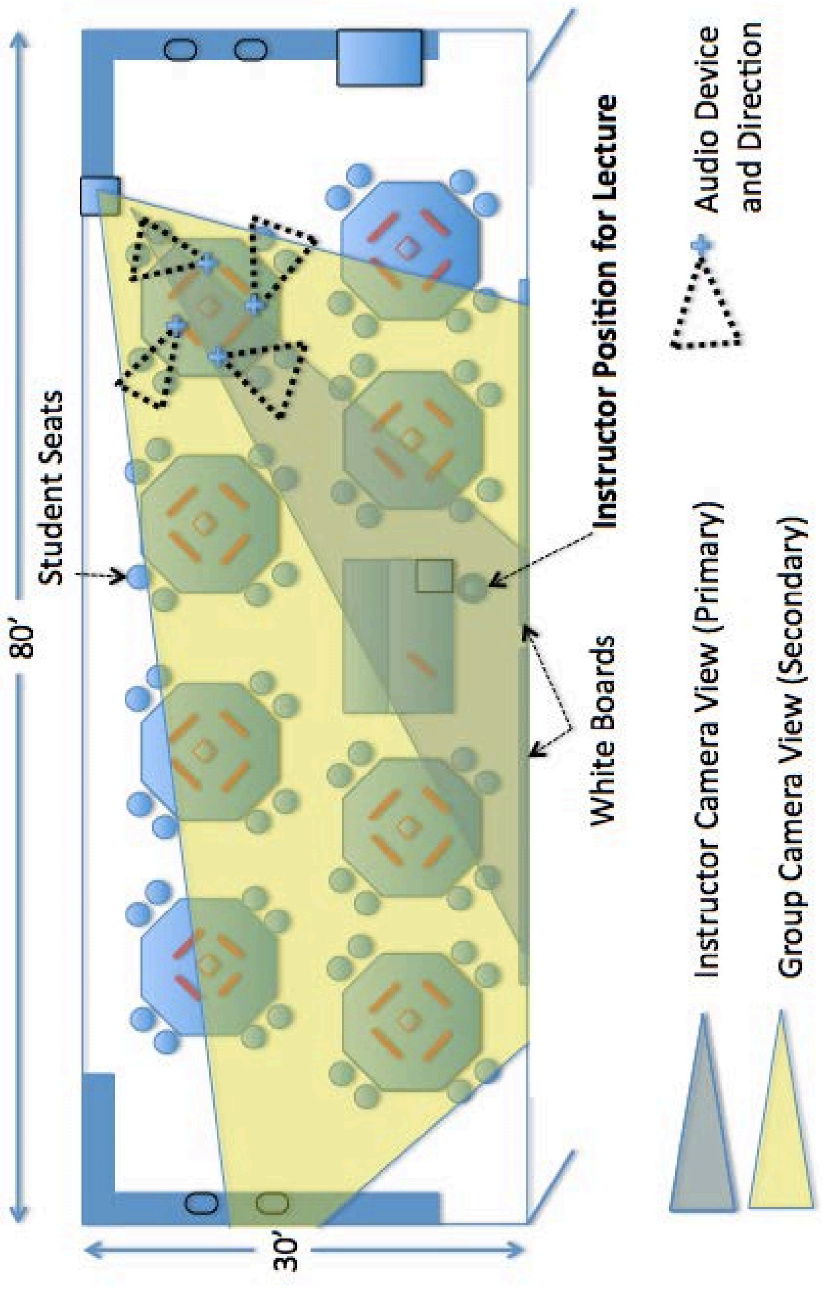
Weade, R. (1987). Curriculum'n'instruction: The construction of meaning. *Theory into Practice, 26*(1), 15-25.

Wood, P. K. (1983). Inquiring systems and problem structure: Implications for cognitive development. *Human Development, 26*(5), 249-265.

Woods, D. R., Hrymak, A. N., Marshall, R. R., Wood, P. E., Crowe, T. W., Hoffman, T. W., et al. (1997). Developing problem solving skills: The McMaster problem solving program. *Journal of Engineering Education*, *86*(2), 75-92.

Appendices

Appendix A: Video and Audio Recorder Positions



Appendix B1: Observation Table for Day 4

Printed: 7/15/12
Page 1 of 8

Observation Tables GenChem AY2012
Wk 2, Tuesday, 10 Jan 2012

Researcher: Melinda Kalainoff

T	RecT	Action by Instructor	Action by students	Ph	Event	N=Note; Ph= Phase of Activity; A=Admin Note;
		Ordering paperwork at instructor bench	Students arriving into class and taking seats		Pre-Class	
			Moving chairs for trio groups			
	2:30	Announcing over mic to class to turn in (1)Excel lab and (2) types of reactions worksheet due today	Taking paperwork to the table in front of the instructor bench			
		Putting on headset for class mic	Talking amongst eachother			
		Telling student where to find a chair for trio group	Continuing to turn in paperwork to table			
		Talking to male TA at instructor bench				
0	7:10	Greeting			Greeting and Admin	
		Providing overview for the week: first experiment on Thurs where students must have pre-lab showing location of pre-lab requirements on online resources; lab report from requirements; guidelines on what a good conclusion includes to be read on the online; when reports are due (showing	Looking at monitors where instructor has put up the prelab requirement sheet from online resource			
		removing online resources from monitor				
		showing blank sheet from elmo overhead				
	12:07	saying that she is continuing with chapter 6 (thermodynamics)	Some getting out different workbook or turning pages; students reposition themselves in seats; still orienting to monitors generally		Lecture: Definitions and Relationships (delH and Energy Diagrams)	
	12:10	Providing summary of last time: system and surroundings	Students writing things down and shifting eyegaze between paper and monitor			
	13:58	Introducing new information: total internal energy (delE= Q+W) and units for Q and W; definition of state function with examples;				N: including diagrams to show how W is not a state function
	20:00	Introducing combustion reaction definition				
	22:14	Introducing energy diagrams: definition, conventions				
	23:15	Focusing on two different parts of del E: Q (handwarmers) and W				
	24:45	showing hands warmers on the overhead so all students can see on the	passing around the handwarmers			
	26:45	T points to student (off camera) and asks if (he?) has a question	[student gains attention of T in some way that is			
		says that there are many ways to calculate for Q and that they are going to talk about some but not right now	[asking question that is inaudible]			
	27:30	continuing with introduction of delH as enthalpy of reaction under constant pressure				
		says that last question was 'how did I calculate that' and addresses this generally with bomb calorimetry, says she will talk about how they will calculate it				
	29:28	introducing definition of exothermic reaction using energy diagram to show what exothermic looks like				
23	29:55					End: 08;35;32 Start: 08;51;58
	1:05	no acknowledgement of late student	student walking in late			
	1:45	Showing example of endothermic reaction using reaction and representation as an energy diagram				
	4:11	Introducing another way to look at heat in terms of breaking and forming bonds				

Appendix B1: Observation Table for Day 4

Observation Tables GenChem AY2012
Wk 2, Tuesday, 10 Jan 2012

Researcher: Melinda Kalainoff

T	RecT	Action by Instructor	Action by students	Ph	Event	N=Note; Ph= Phase of Activity; A=Admin Note;
32	8:47	Assigning number 8 in workbook for students to work on their own and then come back together; placing workbook problem 8 on monitor	many students getting new paper; some refering to monitor; some just looking at paper some and monitor	P Posing Problem	Workbook Problem	N: some may have workbook in front of them hardcopy
	11:45	Looking around room	no talking is heard between students			Ph: Student work individually
	12:13	writes and explains answer				Ph: P reviewing solution
	12:57	orienting to her left and lifting head and saying 'yes'	[student question inaudible]	Students asking Question		
		saying 'yes you could cuz you know it'	[inaudible: asking what is required to put on energy diagram, like delH number?]			
		"yes, to make the picture complete, if you have the amount [circling delH on question 8], then you should put the amount in [circling delH amount on diagram]"	[inaudible: asking a followup question about			
		explaining that you put everything that you know on the diagram depending on what you were given in problem				
	14:15	explained how energy diagram is not representative of looking at delH from a bond energy perspective				
38	14:45	transitioning to stoichiometry in thermochemical equans as first way of using enthalpy			Lecture: ThermoChem Eqns	
		defining thermochemical equation				
39:30	16:27					End: 08;51;58 start: 09;21;56
		proposing stoichiometry as chemistry math in the ways she is showing how delH and chemical reactions are related				
44	4:26	Proposing to do a calculation using same reaction just explained.			WorkBook Problem	
		writing question on notes shown to students on monitor and explaining assumptions				
	6:15	asking students what she is going to start with				Ph: metadiscourse through problem
	6:29	says 'the heat you want' and restates as 'you start with the heat you need'	[unclear if a student responds here]			
		explains thought process using dimensional analysis to get what you want from what you have				
		explains how to find significant figures				
	8:58	Proposing that student do problem from the workbook: translating a word problem into a reaction first	adjusting in chairs; getting new paper or turning page in notebook		Workbook Problem 19b	
	9:20	placing workbook problem on overhead and reading problem 19b				
	10:45	T moving down middle aisle to and from the camera				
		T looking over paperwork at table in front of T bench				
		T moving down middle aisle away from camera and moving back to T bench				
	12:09	asking for show of hands to see how many got it	some students raise hands			
		writing solution and explaining what she is writing down; intermittently asking for input from students				
	13:21	adding another level of information and asking another question as a subquestion to the previous problem				
	14:07	telling students to try this	Students working on problem individually		blem	Q: where does this problem come from?

Appendix B1: Observation Table for Day 4

Printed: 7/15/12
Page 3 of 8

Observation Tables GenChem AY2012
Wk 2, Tuesday, 10 Jan 2012

Researcher: Melinda Kalainoff

T	RecT	Action by Instructor	Action by students	Ph	Event	N=Note; Ph= Phase of Activity; A=Admin Note;
	15:48		students whispering to eachother; group closest to camera checking eachothers work		Workbook Pro	
	16:16	asking if anyone has an answer yet	[inaudible response]			
		saying 'I heard that' and repeats solution 39000 kJ				
		asking 'what do I start with'				
		talking through solution using method used previously: what you need from what you have				
57	17:16	trying another one from notebook: stoichiometry and conversions		P providing guidance for problem	Workbook Problem	
		explaining question and giving some guidance				
	18:36	asking if students need control of computer to look up conversions; decides to maintain control to keep up question and provide conversions				
		asking what is one of the first conversions student will need	student responding: gallons			
		saying: gallons to what	[inaudible response]			
	19:07	saying: to liters exactly	students working on problelm individually; little ineraction between students			N: TA passing out blue sheets
	20:25	writing conversions on overhead (gal to L; mile to km; molar mass of C and	partners talke to eachother intermittently	Students working problem independently		
	22:44	using calculator at T bench				
	24:57	talking with TAs				
	27:21	conversing with TA	increasing talking between students discussing the problem			
	28:45	moving around classroom				
69:30	29:52					End: 09;21;56 Start: 09;29;22
		walking down aisle towards camera then away, looking from side to side	students continue to talk about problem: 'energy' 'hours' 'convert'			
	2:58	walking down aisle towards camera then away, looking from side to side				
	3:30	student asking question; orienting to paper; T takes paper back to her bench				
		walking down aisle towards camera then away, looking from side to side				
		returnin to T bench				
	6:04	T responding	student walking up to T bench and asking question			
77	7:27		increasing student talk between eachother	P reviewing solution		End: 9;21;56 Start: 09;59;26
	0:25	saying that she can tell when the noise level goes up that students are	student talking decreases considerably			
		writing reaction on the overhead; contextualizing problem by explaining what is known	no talking is heard between students; orienting to monitors			
		explaining the steps in the answer, intermittently asking for student input				
		explaining why writing out all conversions in dimensional analysis is helpful				N: disciplinary conventions
	3:20	explaining that part of her goal is to reteach them the art of estimating				N: disciplinary conventions
	4:44	explaining that this answer will be used to figure out second part of problem				
		explaining solution, intermittently asking for student input				
	5:52	asking if student has a question	[asking question that is inaudible]			
		responding with addressing notation (sign)				
83	6:30	says that they will finish this with one more way to find delH		cing cept		
		explaining delHo as standard enthalpy of reaction				

Appendix B1: Observation Table for Day 4

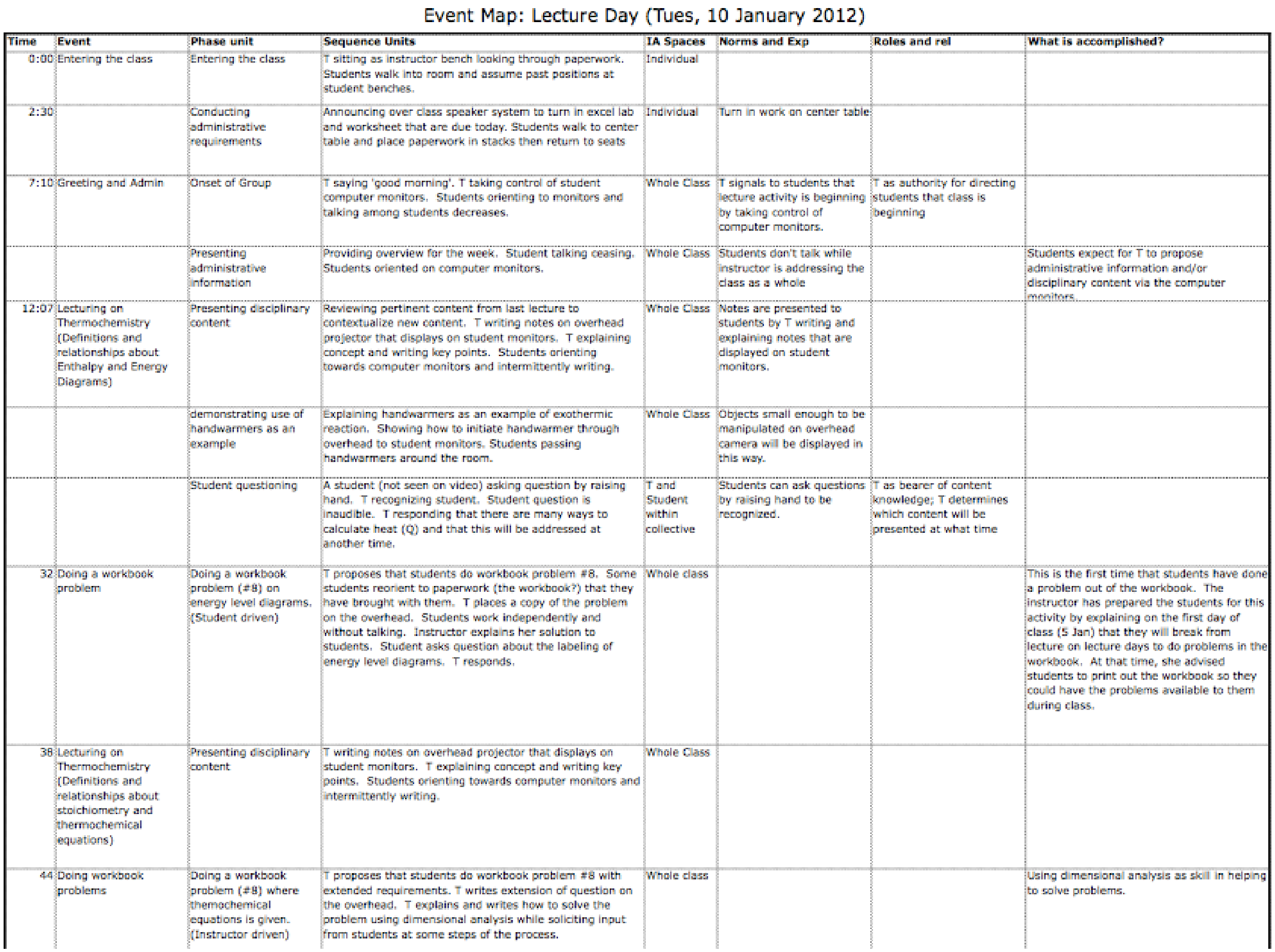
Printed: 7/15/12
Page 4 of 8

Observation Tables GenChem AY2012
Wk 2, Tuesday, 10 Jan 2012

Researcher: Melinda Kalainoff

T	RecT	Action by Instructor	Action by students	Ph	Event	N=Note; Ph= Phase of Activity; A=Admin Note;
	11:30	explaining delHof as standard enthalpy of formation		Introdu the con	Lecture: define std delH	A: adjust camera to wider shot to show most of class
	14:50	explaining delHrxn as prod-reactants				
92:20	15:20	transitioning to problem 26 in workbook which she will have them do on	students adjusting or replacing papers	Doing Workbook Prob as example		Ph: Proposing problem & context
		working out problem while explaining how to do it				Ph: P providing soln through metadiscourse
	21:55	asking if that makes sense to people				Ph: P providing explicit expectations
	22:05	telling students what is required to show to get credit for the problem				
99:45	22:45	presenting last problem for the lesson and telling students they can stay and do the problem or leave		Proposing Problem	Workbook Problem	
		saying they will write the reaction together to get started				
		explaining problem	adjusting in seat; get paper or turn page	Providing initial start to problem		
		explaining how she is making decisions about how to balance the reaction				
		explaining heat of formation table				
		reiterating that students can do this problem in class or do on their own	no one leaves			
	24:55	providing guidance for lab for Thursday: no closed toed shoes				
		announcing they will come back to class group and go over problem together	some students talking to eachother			
	26:04	goes to back lab area	all working on problem; no one leaving	Students work independently		
		T returning to center of room	increase in student talk			
			increase in movement; students packing			
	27:16	asks student what they got	[inaudible response]	Reviewing Soln		Ph: providing metadiscourse
		repeats response and acknowledges correct answer	one student departs after finding out answer			
		provides steps to answer				
105	28:17	releases computer	many students get up and talking level increases significantly		Closing	
		continuing to talk about her office hours and minor announcements	moving out of classroom			
107	29:58		departing classroom			End: 09;59;26 Start: 10;01;26

Appendix B2: Event Map for Day 4



Event Map: Lecture Day (Tues, 10 January 2012)

Time	Event	Phase unit	Sequence Units	IA Spaces	Norms and Exp	Roles and rel	What is accomplished?
0:00	Entering the class	Entering the class	T sitting as instructor bench looking through paperwork. Students walk into room and assume past positions at student benches.	Individual			
2:30		Conducting administrative requirements	Announcing over class speaker system to turn in excel lab and worksheet that are due today. Students walk to center table and place paperwork in stacks then return to seats	Individual	Turn in work on center table		
7:10	Greeting and Admin	Onset of Group	T saying 'good morning'. T taking control of student computer monitors. Students orienting to monitors and talking among students decreases.	Whole Class	T signals to students that lecture activity is beginning by taking control of computer monitors.	T as authority for directing students that class is beginning	
		Presenting administrative information	Providing overview for the week. Student talking ceasing. Students oriented on computer monitors.	Whole Class	Students don't talk while instructor is addressing the class as a whole		Students expect for T to propose administrative information and/or disciplinary content via the computer monitors.
12:07	Lecturing on Thermochemistry (Definitions and relationships about Enthalpy and Energy Diagrams)	Presenting disciplinary content	Reviewing pertinent content from last lecture to contextualize new content. T writing notes on overhead projector that displays on student monitors. T explaining concept and writing key points. Students orienting towards computer monitors and intermittently writing.	Whole Class	Notes are presented to students by T writing and explaining notes that are displayed on student monitors.		
		demonstrating use of handwarmers as an example	Explaining handwarmers as an example of exothermic reaction. Showing how to initiate handwarmer through overhead to student monitors. Students passing handwarmers around the room.	Whole Class	Objects small enough to be manipulated on overhead camera will be displayed in this way.		
		Student questioning	A student (not seen on video) asking question by raising hand. T recognizing student. Student question is inaudible. T responding that there are many ways to calculate heat (Q) and that this will be addressed at another time.	T and Student within collective	Students can ask questions by raising hand to be recognized.	T as bearer of content knowledge; T determines which content will be presented at what time	
32	Doing a workbook problem	Doing a workbook problem (#8) on energy level diagrams. (Student driven)	T proposes that students do workbook problem #8. Some students reorient to paperwork (the workbook?) that they have brought with them. T places a copy of the problem on the overhead. Students work independently and without talking. Instructor explains her solution to students. Student asks question about the labeling of energy level diagrams. T responds.	Whole class			This is the first time that students have done a problem out of the workbook. The instructor has prepared the students for this activity by explaining on the first day of class (5 Jan) that they will break from lecture on lecture days to do problems in the workbook. At that time, she advised students to print out the workbook so they could have the problems available to them during class.
38	Lecturing on Thermochemistry (Definitions and relationships about stoichiometry and thermochemical equations)	Presenting disciplinary content	T writing notes on overhead projector that displays on student monitors. T explaining concept and writing key points. Students orienting towards computer monitors and intermittently writing.	Whole Class			
44	Doing workbook problems	Doing a workbook problem (#8) where themochemical equations is given. (Instructor driven)	T proposes that students do workbook problem #8 with extended requirements. T writes extension of question on the overhead. T explains and writes how to solve the problem using dimensional analysis while soliciting input from students at some steps of the process.	Whole class			Using dimensional analysis as skill in helping to solve problems.

Appendix B2: Event Map for Day 4

Event Map: Lecture Day (Tues, 10 January 2012)

49		Doing a workbook problem (#19b) where thermochemical equation is derived. (Student driven)	T proposes that students do workbook problem #19b and presents problem. Students work on problem independently. T walks up and down middle aisle. Returns to T bench and asks how many students got it. T explains and writes solution while soliciting input from students at some steps of the process.	Individually within collective			
53		Doing a workbook problem (#19b) where question is extended. (Student driven)	T proposes that students do workbook problem #19b with extended requirements. Students work on problem independently. T walks up and down middle aisle. Returns to T bench and asks how many students got it. T explains and writes solution while soliciting input from students at some steps of the process.	Individually within collective			
57		Doing a workbook problem that requires multiple parts (Student driven)	T proposes that students do workbook problem. Asks if students need access to computer for conversions. Decides to provide students with conversions. Students work on problem independently. T walks up and down middle aisle. A student asks a question. T responds and continues to walk up and down middle aisle. Returns to T bench and asks how many students got it. Student talk increases. T comments that she can always tell when most students are done with the problem. T explains and writes solution while soliciting input from students at some steps of the process.	Individually within collective		T allows most students to complete problem before providing a solution	Explanation includes: 1) why writing out all the conversions is helpful and 2) explaining that part of her goal is to reteach students the art of estimating
83	Lecturing on Thermochemistry (Definitions and relationships about standard enthalpy of rxn and formation)	Presenting disciplinary content	T writing notes on overhead projector that displays on student monitors. T explaining concept and writing key points. Students orienting towards computer monitors and intermittently writing.	Whole Class			
92	Doing workbook problems	Doing a workbook problem (#26) (Instructor driven)	T proposes that students do workbook problem #26 and presents problem. T explains and writes solution.	Whole Class			
100		Doing a workbook problem (Student driven)	T proposes a problem solving for enthalpy of reaction using product enthalpies and reactant enthalpies. Students work on problem individually. T provides guidance for lab on Thursday and reminds students that she will be going over the solution to the problem for those who want to stay. Students continue working on problem. T asks students what they got. T repeats and acknowledges correct answer and provides steps to answer.	Individually within collective			Says it is the last problem of the day and that students can stay and complete it or leave; all students stayed.
105	Concluding class		T releases control of computers back to students and makes minor announcements. Students begin moving once computers control has been returned to students.	Individually within collective	T provides standards by which students can end their participation in the class for the day	Signaling the end of class	

Appendix C1: Observation Table for Day 5

Printed: 7/15/12
Page1of6

Observation Tables for GenChem AY2012
Wk 2, Thursday, 12 Jan 2012

Researcher: Melinda Kalainoff

T	RecT	Action by Instructor	Action by students	Ph	Event	N=Note; Ph= Phase of Activity; A=Admin Note; Q=Question
0		[hardcopy notes showing coverage of content is available: beginning calorimetry as a way of measuring delH	oriented on monitor; taking notes	Introducing definitions for heat	Lecture	A: [started taping late: time zero is official class start time for this day only]
10	0:00	talking about heat capacity				
	0:36	proposing example problem 14 in workbook	adjusting papers	Doing problem (T led for q=mcdelT)		
		proposing that students need to think about different ways in finding Q				
	2:00	explaining how to think through the problem				N: P provides metadiscourse through
		addressing how units cancel				
		introducing calculating Q for phase changes				
	3:12	providing final answer				
14	3:50	introducing how to find enthalpy for phase changes (isothermal processes)		Introducing Definitions and concepts for phase changes		
		defining states of matter in terms of movement				
	9:42	introducing heating curves				
	13:25	recognizing student	For delH asking if going backwards on the heating curve has negative			
		acknowledging and explaining that going in opposite direction on diagram changes the sign				
24	14:22	proposing calculation that has temp changes and phase changes: number 16 from workbook			oblem (Instructor led calculation with temp and phase changes)	
		writing down problem on overhead				
	16:20	explaining question				
	16:58	working through problem				
	17:59	saying that this is one too many steps to put on a quiz but not an exam				N: T providing expectations for exam
	20:13	asking students to use calculator to find final answer	obtaining calculators and using			N: independently calculating with
	21:15	saying that everyone needs to know how to do this because this concept will be on the quiz	students working on calculation (just the math b/c T set up the			N: explainin math:distribution of a variable
	24:00		little student talk			
	25:00	explains that it's important to watch the signs on both sides of equation and relationship to physical				
	26:03	asking for final answer	[response is inaudible]			
	26:13	Explaining rationale for answer: sign, sig figs				
		asking students if that makes sense	[student asking question;			

Appendix C1: Observation Table for Day 5

Printed: 7/15/12
Page2of6

Observation Tables for GenChem AY2012
Wk 2, Thursday, 12 Jan 2012

Researcher: Melinda Kalainoff

T	RecT	Action by Instructor	Action by students	Ph	Event	N=Note; Ph= Phase of Activity; A=Admin Note; Q=Question
	27:00	providing reasons why the answer makes sense			Doing a workbook pi	
	27:23		[student asking question:			
		saying Deposition is gas to a solid; explaining vapor deposition				
	28:04		Student asking question: what does n(delH) represent?			
		explaining it is the delH for phase changes and that this is great lead in to the lab today				
38	28:20	explaining overview of lab: heat transfer to cause sublimation		Posing Content	PreLab	Ph: proposing content for the lab
		providing main equation for lab				
		announcing requirement for students to run the experiment three times and share delH values with other groups at table		Reviewing Procedures		Ph: Reviewing lab procedures and admin Admin: table is group of 8; N: use temp prob vs. pH meter
		explaining experimental set up and measurement tools				
	33:45	explaining key safety guidelines: use of dry ice, use goggles and gloves		Reviewing Safety		Ph: Reviewing safety guidelines and final admin
		explaining admin issues for quiz and locations of items for lab report				
	33:58	checking to see if server is back up: chemweb is down		Transition		N: "chemweb" is site that has lab info
	34:45	releasing control of computers and removing mic	students getting out of chairs and obtaining equipment			
	35:22	announcing admin guidance: put out lab notebooks, get backpacks out of walkways, write names on seating chart that is being passed around	donning goggles	Setting up experiment		
			putting out pre-lab on table for checks by Tas			
			obtaining styrofoam coffee cups			
	38:22					A: T mic is recorded on audio
	38:50	announcing that chemweb is up				
	41:51	telling TA that she (T) needs to do the key for lab today				
			S asking if the water has to be at the 60 gram mark			
		T responding that no, but as long as he records what he does have				
	43:24	TA asking T about career possibilities that include and education component: discussing with TA	students continuing to set up experiment			
			student asking what to do if he dropped some dry ice			

Appendix C1: Observation Table for Day 5

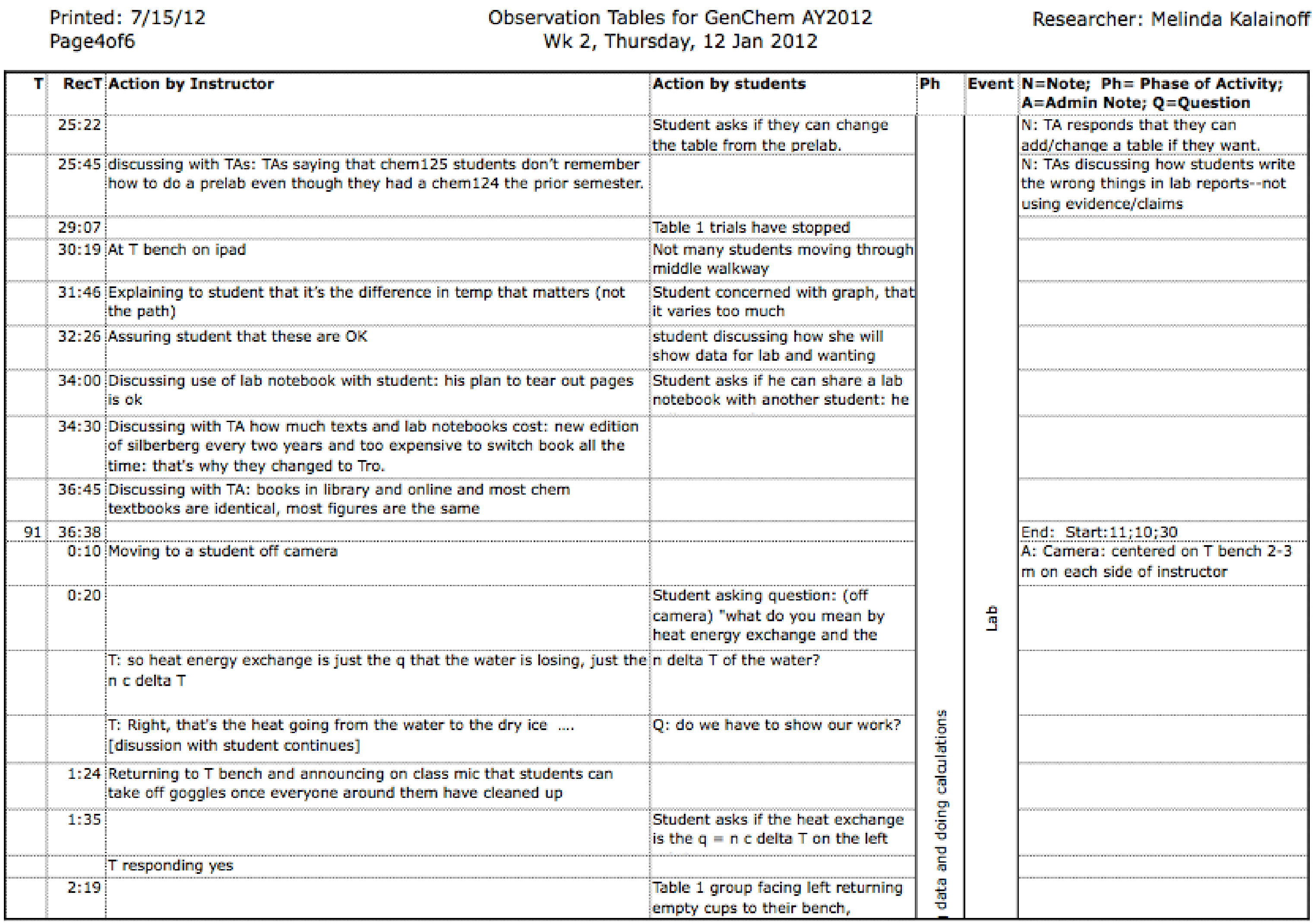
Printed: 7/15/12
Page3of6

Observation Tables for GenChem AY2012
Wk 2, Thursday, 12 Jan 2012

Researcher: Melinda Kalainoff

T	RecT	Action by Instructor	Action by students	Ph	Event	N=Note; Ph= Phase of Activity; A=Admin Note; Q=Question
		responding to account for it by weighing		Conducting Lab Trials		
55	45:27	asking TA if he was interested in doing something in chemical education; discussing with TA				End: 09;58;40 Start: 10;35;22
	0:00	continuing to talk to TA about PhD				
			Student question about recording the temperature			
	0:30	Responding to student	Student departs T area			
	0:45	Continuing to talk to TA about PhD				
	3:10		Student asking question of T about when they should have started recording temperature			
	4:30	Responding to student	Student departs T area			
	4:40	Continuing to talk to TA about PhD and chemistry upper level courses				
	7:31	"	Students conducting experiment			N: Table 1 facing away from camera
	10:25	"	Another group conducting a trial			N: Table 1 facing towards left
	13:07	trying to download and receiving TA assistance; discussing with TA				
	14:50	discussing with TA about making quiz a take home and when to cover certain material knowing there is a day off (Next Monday is a Tuesday); should start lecturing after the quiz; discussing lecturing before or lecturing after				N: long discussion with TAs about when to lecture considering graded events and missing of one day next week
	19:04	Talking to TAs about the male TAs background and their own majors				Male TA departs; one TA says there is no chemical engineering major here
	21:25		Table 1 (facing left) starts new trial			
	21:40		Table 3 (facing camera) starts new			
		says that she wasn't aware that automotive was considered engineering				
	22:50	discussing problems with tare on balance with TAs				
	23:25		Student asks where they should write calculations in lab book or			
		responding to student				
	24:25		Tables 1 trials continuing			
	24:40		Student asks that if they are ready to do the calculations, if they have to do them in the lab notebook.			
		Responds, no that they don't have to because they will show a sample in the report.				

Appendix C1: Observation Table for Day 5



Printed: 7/15/12
Page4of6

Observation Tables for GenChem AY2012
Wk 2, Thursday, 12 Jan 2012

Researcher: Melinda Kalainoff

T	RecT	Action by Instructor	Action by students	Ph	Event	N=Note; Ph= Phase of Activity; A=Admin Note; Q=Question
	25:22		Student asks if they can change the table from the prelab.	data and doing calculations	Lab	N: TA responds that they can add/change a table if they want.
	25:45	discussing with TAs: TAs saying that chem125 students don't remember how to do a prelab even though they had a chem124 the prior semester.				N: TAs discussing how students write the wrong things in lab reports--not using evidence/claims
	29:07		Table 1 trials have stopped			
	30:19	At T bench on ipad	Not many students moving through middle walkway			
	31:46	Explaining to student that it's the difference in temp that matters (not the path)	Student concerned with graph, that it varies too much			
	32:26	Assuring student that these are OK	student discussing how she will show data for lab and wanting			
	34:00	Discussing use of lab notebook with student: his plan to tear out pages is ok	Student asks if he can share a lab notebook with another student: he			
	34:30	Discussing with TA how much texts and lab notebooks cost: new edition of silberberg every two years and too expensive to switch book all the time: that's why they changed to Tro.				
	36:45	Discussing with TA: books in library and online and most chem textbooks are identical, most figures are the same				
91	36:38					End: Start:11;10;30
	0:10	Moving to a student off camera				A: Camera: centered on T bench 2-3 m on each side of instructor
	0:20		Student asking question: (off camera) "what do you mean by heat energy exchange and the			
		T: so heat energy exchange is just the q that the water is losing, just the n c delta T	n delta T of the water?			
		T: Right, that's the heat going from the water to the dry ice .... [disussion with student continues]	Q: do we have to show our work?			
	1:24	Returning to T bench and announcing on class mic that students can take off goggles once everyone around them have cleaned up				
	1:35		Student asks if the heat exchange is the q = n c delta T on the left			
		T responding yes				
	2:19		Table 1 group facing left returning empty cups to their bench,			

Appendix C1: Observation Table for Day 5

Printed: 7/15/12
Page5of6

Observation Tables for GenChem AY2012
Wk 2, Thursday, 12 Jan 2012

Researcher: Melinda Kalainoff

T	RecT	Action by Instructor	Action by students	Ph	Event	N=Note; Ph= Phase of Activity; A=Admin Note; Q=Question
	4:01	at bench writing and using calculator	Table 1 group facing left using	Organizin		
	5:43	Announcing to class with mic that lab is due next Thursday because next Tuesday is Monday (no Tuesday class)				
	6:20	discussing admin lab details with TA				
	6:53		Student asking to borrow			
		T giving student a calculator				
	7:51	T using a calculator at instructor Bench	little movement across camera			
	9:39	telling student that she wants them to do all the work in word using equation editor so that TAs can grade these easier	Student asking if she wants them to do the report in word.			
	10:12	discussing what the heat exchange is in terms of the equation	Student follow up question about what the heat exchange is.			
	10:23	discussing with female student that she needs procedure and data tables on prelab copy and conclusions go on the report form.	Female student asks when the report form is due and where the calculations should be			N: conclusion goes on report form, calculations could be in either prelab or report; prelab is attached to the lab
	11:15	Moving to student	Student asking about calculations			
		discussing calculations with student group				
	12:28	moving back to instructor bench: announcing to students over mic the magnitude of the heat of sublimation just so they have an idea				
		Discussing with a student what is required for turning in	Student asking T about requirements for turning in prelab			
	13:27	Announcing to students to turn in the carbon copy of prelab, doesn't need other people data or calculations, just the student's data				
	15:00	Answering mutiple questions about turning in pre-lab, using equation editor, admin points with Tas				
			Student asking about what the sign should be			
	16:26	T discussing with student that this is what he is supposed to find out; with guidance				
	17:05		Many student moving around, through camera angle with paper			
	18:15		Student asking about the difference between heat of sublimation and the heat			N: using equations to explain heat exchange
		T responding to students				

Appendix C1: Observation Table for Day 5

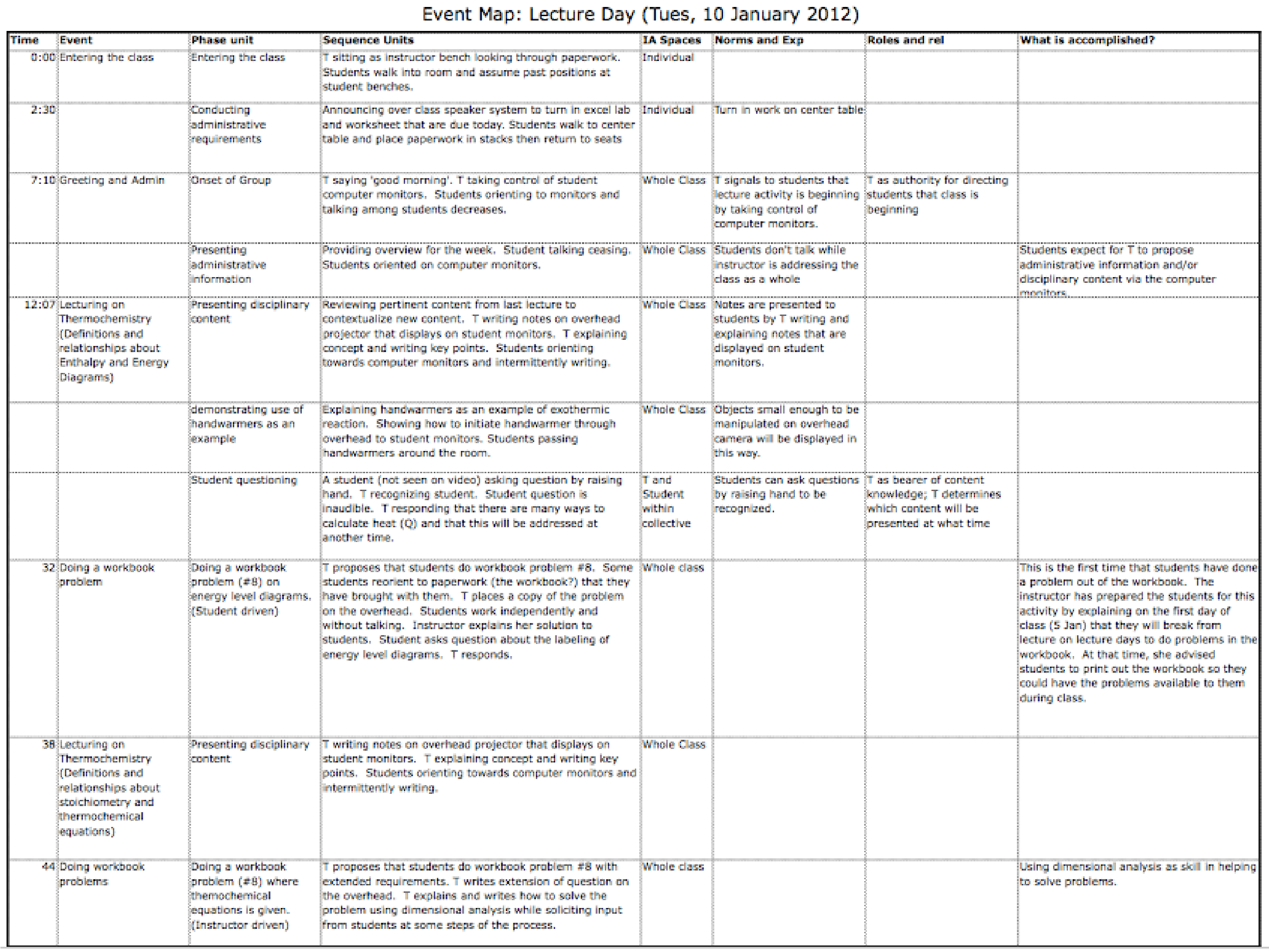
Printed: 7/15/12
Page6of6

Observation Tables for GenChem AY2012
Wk 2, Thursday, 12 Jan 2012

Researcher: Melinda Kalainoff

T	RecT	Action by Instructor	Action by students	Ph	Event	N=Note; Ph= Phase of Activity; A=Admin Note; Q=Question
	18:52	T responding by laughing and saying that they would start with the data... implying that it's complicated or that it means extra work	Student asking how they would do sig figs	Clean up and Turning in Pre-lab		
	20:03		Table 1 facing left packing backpack and departing; Table 1 facing away from camera too			
			Table 3 groups 1 and 3 collecting gear to depart; group 2 discussing with T w backpack			A: Camera pans few feet to the right to cover all of T bench
	21:00	Discussing admin with students				
			Little movement across camera anglea and students putting paper on desk pile with backpacks			
	25:08	discussing with TA that student will turn in pre-labs the first couple of times during class and then turn in with lab reports thereafter.	TA asking about lab score and pre-lab			
	25:15	discussing with student that he should do the problems from the workbook and check his answers; those that he has problems with, then find problem like that in the book and try those; chapter 6 and stuff for chapter 11 on phase changes.	Student commenting on what he can do to work on the quiz for tomorrow			
	26:45	Going to be calculations, show your work type stuff	Same student asking what the test			
	27:15	Talking to researcher about her jewerly crafts and other non-chemistry topics.				
	29:00	T telling researcher that she will do a quiz tomorrow and explaing challenges with losing a day of class next week.				
	30:36	Next week's lab: calculating heat of combustion by hess's law.				N: Only conversation is between researcher and T: all students gone?
125	34:05					End:

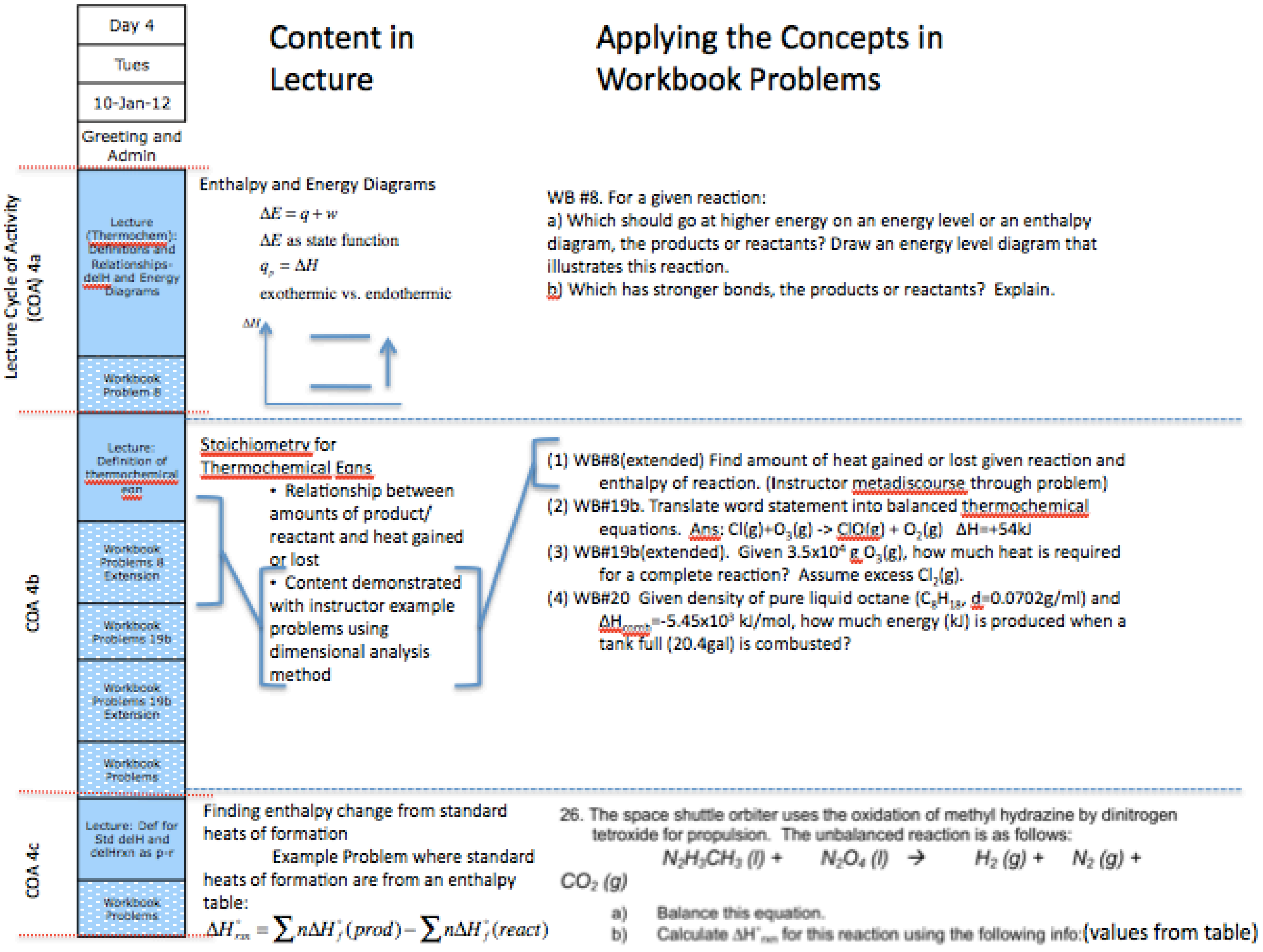
Appendix C2: Event Map for Day 5



Event Map: Lecture Day (Tues, 10 January 2012)

Time	Event	Phase unit	Sequence Units	IA Spaces	Norms and Exp	Roles and rel	What is accomplished?
0:00	Entering the class	Entering the class	T sitting as instructor bench looking through paperwork. Students walk into room and assume past positions at student benches.	Individual			
2:30		Conducting administrative requirements	Announcing over class speaker system to turn in excel lab and worksheet that are due today. Students walk to center table and place paperwork in stacks then return to seats	Individual	Turn in work on center table		
7:10	Greeting and Admin	Onset of Group	T saying 'good morning'. T taking control of student computer monitors. Students orienting to monitors and talking among students decreases.	Whole Class	T signals to students that lecture activity is beginning by taking control of computer monitors.	T as authority for directing students that class is beginning	
		Presenting administrative information	Providing overview for the week. Student talking ceasing. Students oriented on computer monitors.	Whole Class	Students don't talk while instructor is addressing the class as a whole		Students expect for T to propose administrative information and/or disciplinary content via the computer monitors.
12:07	Lecturing on Thermochemistry (Definitions and relationships about Enthalpy and Energy Diagrams)	Presenting disciplinary content	Reviewing pertinent content from last lecture to contextualize new content. T writing notes on overhead projector that displays on student monitors. T explaining concept and writing key points. Students orienting towards computer monitors and intermittently writing.	Whole Class	Notes are presented to students by T writing and explaining notes that are displayed on student monitors.		
		demonstrating use of handwarmers as an example	Explaining handwarmers as an example of exothermic reaction. Showing how to initiate handwarmer through overhead to student monitors. Students passing handwarmers around the room.	Whole Class	Objects small enough to be manipulated on overhead camera will be displayed in this way.		
		Student questioning	A student (not seen on video) asking question by raising hand. T recognizing student. Student question is inaudible. T responding that there are many ways to calculate heat (Q) and that this will be addressed at another time.	T and Student within collective	Students can ask questions by raising hand to be recognized.	T as bearer of content knowledge; T determines which content will be presented at what time	
32	Doing a workbook problem	Doing a workbook problem (#8) on energy level diagrams. (Student driven)	T proposes that students do workbook problem #8. Some students reorient to paperwork (the workbook?) that they have brought with them. T places a copy of the problem on the overhead. Students work independently and without talking. Instructor explains her solution to students. Student asks question about the labeling of energy level diagrams. T responds.	Whole class			This is the first time that students have done a problem out of the workbook. The instructor has prepared the students for this activity by explaining on the first day of class (5 Jan) that they will break from lecture on lecture days to do problems in the workbook. At that time, she advised students to print out the workbook so they could have the problems available to them during class.
38	Lecturing on Thermochemistry (Definitions and relationships about stoichiometry and thermochemical equations)	Presenting disciplinary content	T writing notes on overhead projector that displays on student monitors. T explaining concept and writing key points. Students orienting towards computer monitors and intermittently writing.	Whole Class			
44	Doing workbook problems	Doing a workbook problem (#8) where themochemical equations is given. (Instructor driven)	T proposes that students do workbook problem #8 with extended requirements. T writes extension of question on the overhead. T explains and writes how to solve the problem using dimensional analysis while soliciting input from students at some steps of the process.	Whole class			Using dimensional analysis as skill in helping to solve problems.

Appendix D: Cycle of Activity (Days 4 and 5)



Day 4

Tues

10-Jan-12

Greeting and Admin

Content in Lecture

Applying the Concepts in Workbook Problems

Lecture Cycle of Activity (COA) 4a

Lecture (Thermochem): Definitions and Relationships- delH and Energy Diagrams

Workbook Problem 8

Enthalpy and Energy Diagrams

$\Delta E = q + w$

ΔE as state function

$q_p = \Delta H$

exothermic vs. endothermic

WB #8. For a given reaction:
a) Which should go at higher energy on an energy level or an enthalpy diagram, the products or reactants? Draw an energy level diagram that illustrates this reaction.
b) Which has stronger bonds, the products or reactants? Explain.

COA 4b

Lecture: Definition of thermochemical eqn

Workbook Problems 8 Extension

Workbook Problems 19b

Workbook Problems 19b Extension

Workbook Problems

Stoichiometry for Thermochemical Eqns

- Relationship between amounts of product/ reactant and heat gained or lost
- Content demonstrated with instructor example problems using dimensional analysis method

(1) WB#8(extended) Find amount of heat gained or lost given reaction and enthalpy of reaction. (Instructor metadiscourse through problem)

(2) WB#19b. Translate word statement into balanced thermochemical equations. Ans: $Cl(g)+O_3(g) \rightarrow ClO(g) + O_2(g)$ $\Delta H=+54kJ$

(3) WB#19b(extended). Given $3.5x10^4$ g $O_3(g)$, how much heat is required for a complete reaction? Assume excess $Cl_2(g)$.

(4) WB#20 Given density of pure liquid octane (C_8H_{18}, d=0.0702g/ml) and ΔH_{comb}=-5.45x10^3 kJ/mol, how much energy (kJ) is produced when a tank full (20.4gal) is combusted?

COA 4c

Lecture: Def for Std delH and delHrxn as p-r

Workbook Problems

Finding enthalpy change from standard heats of formation

Example Problem where standard heats of formation are from an enthalpy table:

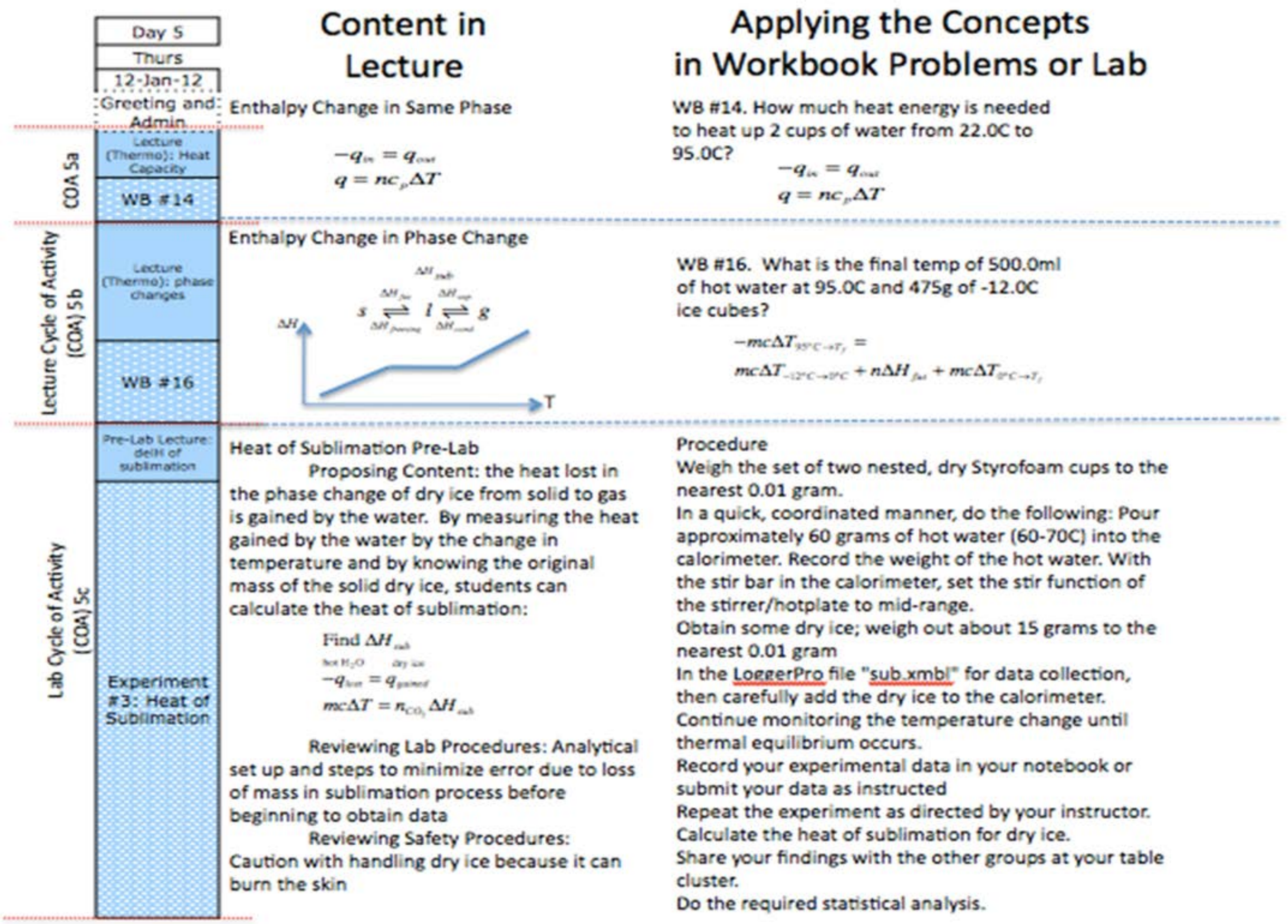
$$\Delta H^\circ_{rxn} = \sum n\Delta H^\circ_f(prod) - \sum n\Delta H^\circ_f(react)$$

26. The space shuttle orbiter uses the oxidation of methyl hydrazine by dinitrogen tetroxide for propulsion. The unbalanced reaction is as follows:

$$N_2H_3CH_3\ (l) + N_2O_4\ (l) \rightarrow H_2\ (g) + N_2\ (g) + CO_2\ (g)$$

a) Balance this equation.
b) Calculate ΔH°_{rxn} for this reaction using the following info:(values from table)

Appendix D: Cycle of Activity (Days 4 and 5)



	Day 5 Thurs 12-Jan-12	Content in Lecture	Applying the Concepts in Workbook Problems or Lab
	Greeting and Admin	Enthalpy Change in Same Phase	
COA 5a	Lecture (Thermo): Heat Capacity WB #14	$-q_{in} = q_{out}$ $q = nc_p\Delta T$	WB #14. How much heat energy is needed to heat up 2 cups of water from 22.0C to 95.0C? $-q_{in} = q_{out}$ $q = nc_p\Delta T$
Lecture Cycle of Activity (COA) 5b	Lecture (Thermo): phase changes WB #16	Enthalpy Change in Phase Change $s \underset{\Delta H_{freezing}}{\overset{\Delta H_{fus}}{\rightleftharpoons}} l \underset{\Delta H_{cond}}{\overset{\Delta H_{vap}}{\rightleftharpoons}} g$, ΔH_{sub} ΔH T	WB #16. What is the final temp of 500.0ml of hot water at 95.0C and 475g of -12.0C ice cubes? $-mc\Delta T_{95^\circ C \to T_f} =$ $mc\Delta T_{-12^\circ C \to 0^\circ C} + n\Delta H_{fus} + mc\Delta T_{0^\circ C \to T_f}$
Lab Cycle of Activity (COA) 5c	Pre-Lab Lecture: delH of sublimation Experiment #3: Heat of Sublimation	Heat of Sublimation Pre-Lab Proposing Content: the heat lost in the phase change of dry ice from solid to gas is gained by the water. By measuring the heat gained by the water by the change in temperature and by knowing the original mass of the solid dry ice, students can calculate the heat of sublimation: Find ΔH_{sub} hot H_2O dry ice $-q_{lost} = q_{gained}$ $mc\Delta T = n_{CO_2}\Delta H_{sub}$ Reviewing Lab Procedures: Analytical set up and steps to minimize error due to loss of mass in sublimation process before beginning to obtain data Reviewing Safety Procedures: Caution with handling dry ice because it can burn the skin	Procedure Weigh the set of two nested, dry Styrofoam cups to the nearest 0.01 gram. In a quick, coordinated manner, do the following: Pour approximately 60 grams of hot water (60-70C) into the calorimeter. Record the weight of the hot water. With the stir bar in the calorimeter, set the stir function of the stirrer/hotplate to mid-range. Obtain some dry ice; weigh out about 15 grams to the nearest 0.01 gram In the LoggerPro file "sub.xmbl" for data collection, then carefully add the dry ice to the calorimeter. Continue monitoring the temperature change until thermal equilibrium occurs. Record your experimental data in your notebook or submit your data as instructed Repeat the experiment as directed by your instructor. Calculate the heat of sublimation for dry ice. Share your findings with the other groups at your table cluster. Do the required statistical analysis.

Appendix E1: Transcript of TA and Professor Discourse in Interactional Space A, Day 7, Figure 7

Line	Professor N	TA
[Students moving around lab and asking questions]		
[TA and instructor positioned at instructor bench and open IA space to discuss how pre-lab was conducted]		
[Start Time: 53:45]		
1	it's weird for me to sit there and listen	
		yeah I bet
		is it good/
	yes	
5	the	
	the elmo is really hard	
		I know
	to work with	
	your first time	
10		my first time
		yeah
		I was getting (inaudible)
		down the page
		without even realizing it
15	and its	
	I should have put it back on the y	
	cuz I had it zoomed in	
		that's probably good it was in
		I write pretty small
20		just naturally
	it was actually zoomed in pretty far	
[Time: 54:11]		
[[IA space disrupted by administrative issues for the lab]]		
[Time: 54:55]		
	were you conscious of being miked/	
		n n
	ok	
25		not really
	was the other microphone [gesturing to headset]	
	was that one cumbersome/	
		it was fine
		I just couldn't hear out of this ear
30		so
		I was like
		when people were saying things
		it was like uh
		I can't hear you
35	yeah	
	they don't tend to talk very loud anyway	
		yeah
		I know

Appendix E1: Transcript of TA and Professor Discourse in Interactional Space A, Day 7, Figure 7

Professor N	TA
[55:10]	
[[IA space disrupted by administrative issues for the lab to include giving control of computers back to students]]	
[56:34]	
and I learned this the hard way	
you can	
in this class you can totally tell	
when they’ve stopped paying attention	
	yeah
	I know
and I know that you got it	
you heard it	
	yeah
um	
and that’s why I used to do all his stuff	
like the calculations and everything	
at the beginning	
but because they start	
they stop paying attention	
I’ve ended up moving it to after	
and do it after they’ve collected some data	
and I don’t	
I still sometimes wonder	
how many of them are listening to me	
but	
	yeah
	I know
[I think more of them are]	[you can totally tell]
because they start moving more	
and there is just a little more talking	
and this background hum	
	yep
and I	
I think you still get it in regular lectures	
but in some ways it’s	
easier to ignore	
you know	
if it were a big lecture hall	
it would definitely be easier to ignore	
but in the smaller labs	
I see the same thing	
that they just	
they just shut off after a while	
and I don’t	
I actually like doing pre-lab lectures	
a little bit more in here (in the studio)	

Appendix E1: Transcript of TA and Professor Discourse in Interactional Space A, Day 7, Figure 7

Line	Professor N	TA
	because they have the computers to look at	
	whereas in the other lec	
	or in the other labs	
	depending on the lab	
85	I think we have gotten rid of a lot of those	
	um	
	the benches used to have the tall things above the sinks	
	those blocked a lot of the views	
	I just don’t like writing on chalkboards in labs	
90	its just cumbersome	
		it really is
		I can totally see that
	and I’m just shocked when I walk down the hallways	
	and there’s people lecturing	
95	my husband doesn’t lecture at all in his labs	
	he’s just like	
	ok	
	you know what you’re supposed to be doing	
	just do it	
100		that’s what I would do
		I hate pre-lab lectures
		like in those labs
		I think it was really helpful today
104		because it’s really helping me out

[59:32]
[[IA space disrupted by administrative issues for the lab- as student question]]

Appendix E2: Transcript of Researcher and Professor Discourse in Interactional Space B, Day 7, Figure 7

Line Professor N Researcher
[Time: 2:09:45]
this is such a hard class for students to teach
for exactly the reasons that I noticed
[inaudible] having a hard time with today
and one of them is this thing (gesturing to document camera)
its just awkward as hell
if you’ve never done it before
and I was watching him
and I had it zoomed in pretty far
so he was going off the page
and then he wasn’t watching
if he was going too
if he was going too far down
and they couldn’t see
every once in a while he’d look
and he’d go oh
and he’d move it up
and
um
I normally don’t do much of a pre-lab lecture
partly because I want to hold them responsible for being ready
for the lab
but I told him to go ahead a do more of it
but he still hit a point
and he noticed it
and I brought it up
you can totally tell
when they aren’t paying attention anymore
because they start talking more
they start moving around more
and he had already covered all the experimental stuff
and safety stuff
and he wanted to go over the calculations
and they were already not paying attention
so I think I learned the hard way
oh I can’t do that before the experiment
I have to wait until after
when they’ve done it all
and they’ve collected all the data
and they are paying attention again
for a while I had a really hard time calling them back
together
but I’ve just gotten
to the point where I just force it
you say you know
ok now everybody I know you
want to get outta here
but we’re going to talk about the calculations

Appendix E2: Transcript of Researcher and Professor Discourse in Interactional Space B, Day 7, Figure 7

Line	Professor N	Researcher
	and trust me	
	this is going help you	
50	and they do pay attention	
	but he had already been talking	[once you see the need is there]
	yeah	
	he had already been talking for 20 minutes	
	half an hour and they were already starting to lose	

[Time: 2:11:28 – IA space interrupted by student question]
[IA space reopens with new topic]

Appendix F: Transcript of Key Segments of Professor Discourse in Day 1 Introduction to the Course

Segment J3-A1 [02:38]

if you're enrolled
please take a seat at a computer
its only if you're crashing
should you be over there
so again if
if you are enrolled in the class
please take a seat at a computer
if you're crashing
you're sitting over there
[Time: 03:47] ok
good morning
let's go ahead and get started
again if you are enrolled in chem 124
you should be sitting at a computer right now
there are still some empty seats over there
so hopefully those will get filled
one way or the other
I think I have a short
so you will have to bear with me
with the microphone
this is the general chemistry studio
and as you can see it's not your typical classroom
um
a lot of you are staring at me
because that is what you are used to
in a typical lecture classroom
but you will not watch me for lectures
you will look at your computer screen
so
if you take a look at your computer screen
there you see what is on my computer
so I can show you whatever I want to
on the computer
or you see what is on this thing over here
this document camera
which we affectionately call elmo
that's where I'll be lecturing
so I'll be writing all my lecture notes
right here
you'll see on the computer screen
and that has some definite advantages
as you can imagine
you can always see what I'm writing
and because I have a microphone
you can always hear what I'm saying
so there is not excuse for not taking notes
um
but

Appendix F: Transcript of Key Segments of Professor Discourse in Day 1 Introduction to the Course

Segment J3-A1 (continued)

the disadvantage is that
it’s a little bit like watching television
you’re not looking at me
there’s just this disembodied voice
coming over the microphone
and so your attention span
might be a little bit less
than what it would normally be
in a lecture classroom
so
even though our class meets
twice a week
for 2 hours and 20 minutes
one of those days is a lab day
the other day is what I call the lecture day
I do not lecture for the entire 2 hours and 20 minutes
we would all go crazy if I did that
I’d lose my voice
and you guys would go to sleep
so
I tend to lecture in little increments
of about 30 minutes or so
and then we stop and do some problems
to apply what I’ve been talking about
in the lecture
ok
so we try to keep it as active
as we can
so
that you guys
can get as much out of this
as you can
and also so that
it’s not really all on me
it’s not all up to me
to get the information to you guys
you guys are actively participating
and learning on your own
through applying
what I’m talking about in lecture
ok
so
it might take a little getting used to
but we’ll feel our way through it
I’ve been doing this for years
many, many years
so I think I’ve got it down

Segment J3-A2 (continued)

[reviewing columns in interactive syllabus online]
[13:42] then there is suggested text problems
as well as a workbook
this workbook is something
that I have put together for this class
it's problems from other textbooks
or problems that I’ve written
that apply the material
that we are going to be covering
this is a workbook that covers the entire term
and so when you print it out
you can either print it all out
at the beginning of the term
or you can print it out in sections
as we cover material
but I strongly recommend
um
doing problems in the workbook
and then if you need extra
[14:15] going to the textbook
or visa-versa
which ever works best for you
but you have to do problems
to succeed in this class
you just can’t come to class
and do the few problems
that we do together in class
you have to work on it
outside of class
about 8 to 10 hours a week
that goes by the 25 by 35 thing
that we have in our college
of how much you should be studying
outside of class
um
the workbook
I will post keys to it
before quizzes and exams
so that you can check your work
but
again
you’re not gonna get anything out of it
unless you actually do the problems
it’s not going to help you
to just look at the keys
and in the last column
is where I put testing information
so you can see that on Friday of this week
[15:01] we have a diagnostic quiz
which is a quiz that covers

Segment J3-A2 (continued)

basic concepts of chemistry
that we won’t cover
other than in the two labs
that we are doing this week
so things like nomenclature
stoichiometry calculations
the gas laws
the types of chemical reactions
we’re gonna cover reactions and gas laws
in the two labs this week
and we will review through
particularly in the first lab
nomenclature concepts
balancing chemical reactions
and some stoichiometry practice
but we’re not covering that formally
that’s stuff that you should have had in high school
and it you have already bought the textbook
you know it’s not covered in the textbook
so our textbook
which typically
textbooks are required
I’m kinda moving slowly away from that
because there is so much information
out there free
on the internet
and there’s ebooks
there’s book in the library
there is nothing special necessarily
about this one general chemistry textbook
other than that it’s been put together
for us
exclusively
its missing the first five chapters
which is again
what you should have gotten in high school chemistry
and so it starts out with chapter 6
which is thermochemistry
which is where we’re gonna start
um
if you are retaking this class
and you have one of the Silberberg textbooks
that’s fine too
ok
there’s
like I said
a generally chemistry textbook
they are all pretty much the same
to be honest
this is the one I’ve chosen

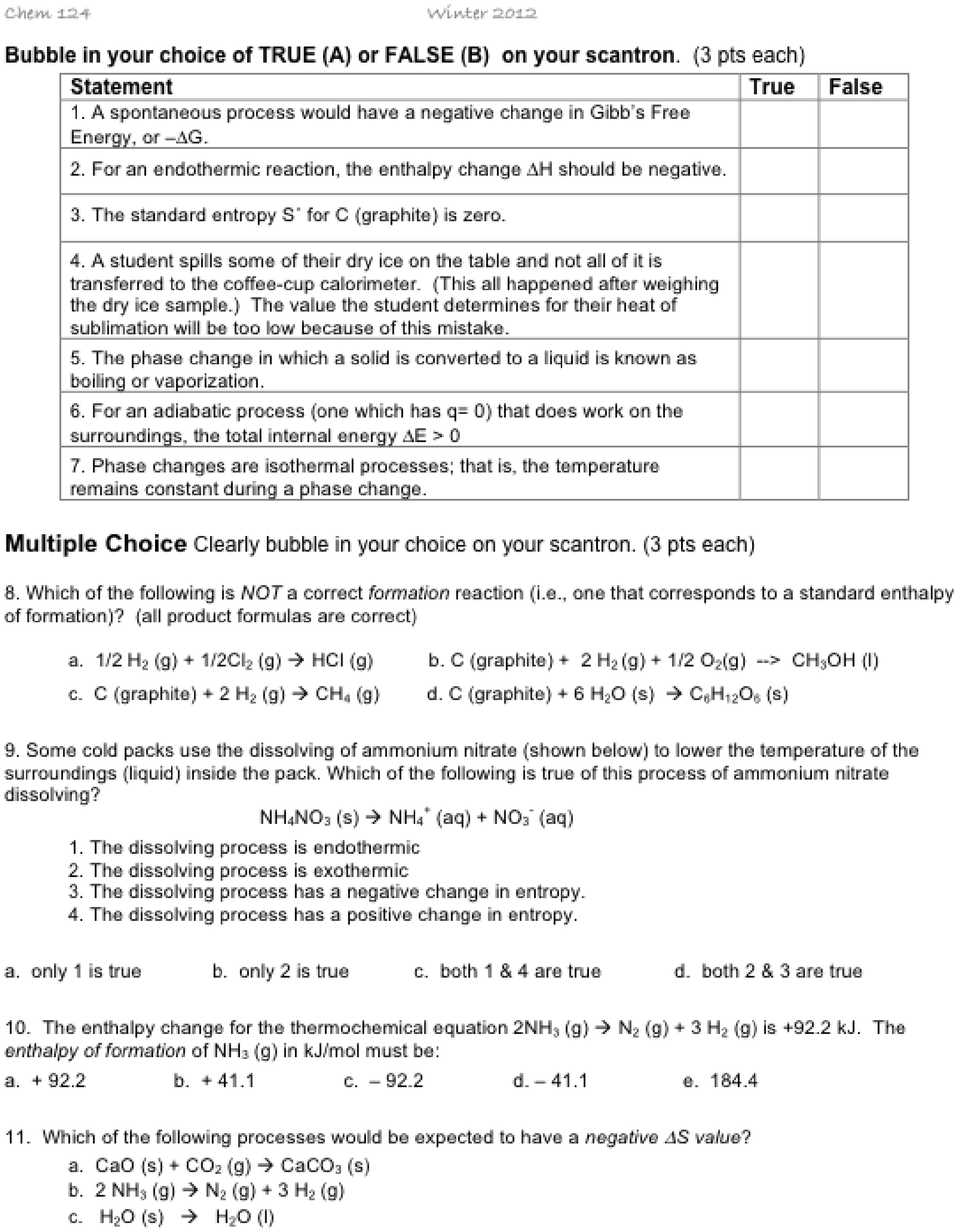
Segment J3-A2 (continued)

partly because I like his method
of
writing
I like the way does practice problems
I think the way he explains things is clear
but if it doesn’t work for you
there’s other textbooks out there
I’m recommending this textbook
but not technically requiring it
and you’ll see on the webpage
that I have recommended problems
both from Tro and Silberberg
which is the book we used to use
and there’s something like six editions of that one
out there
and
[17:20] none of them are very different from each other
I don’t know if other people have moved down
since I started talking
but if you are enrolled in the class
please sit at a computer

Segment J3-A3 [Reviewing syllabus- grading]

[37:12]there’s three
fifty minute exams
and a comprehensive
all multiple choice final
which is also listed at the bottom of the schedule
and online
[37:21] I don’t collect homework
but like I said before
you can’t survive this class
unless you work on problems
and you may have extra sheets
that I give to you to work in class
or we might just work on the workbook problems
its important that you print that out
and bring that with you to class
because when I say
ok
we are going to do this problem
you need to have that workbook in front of you
the full details of the grading are online
and I’ll show you where that is
[37:52] I don’t give make up quizzes or exams

Appendix G1: Assessment, Exam 1



Chem 124 Winter 2012

Bubble in your choice of TRUE (A) or FALSE (B) on your scantron. (3 pts each)

Statement	**True**	**False**
1. A spontaneous process would have a negative change in Gibb's Free Energy, or $-\Delta G$.		
2. For an endothermic reaction, the enthalpy change ΔH should be negative.		
3. The standard entropy S° for C (graphite) is zero.		
4. A student spills some of their dry ice on the table and not all of it is transferred to the coffee-cup calorimeter. (This all happened after weighing the dry ice sample.) The value the student determines for their heat of sublimation will be too low because of this mistake.		
5. The phase change in which a solid is converted to a liquid is known as boiling or vaporization.		
6. For an adiabatic process (one which has q= 0) that does work on the surroundings, the total internal energy $\Delta E > 0$		
7. Phase changes are isothermal processes; that is, the temperature remains constant during a phase change.		

Multiple Choice Clearly bubble in your choice on your scantron. (3 pts each)

8. Which of the following is *NOT* a correct *formation* reaction (i.e., one that corresponds to a standard enthalpy of formation)? (all product formulas are correct)

a. $1/2\ H_2\ (g) + 1/2Cl_2\ (g) \rightarrow HCl\ (g)$ b. $C\ (graphite) + 2\ H_2(g) + 1/2\ O_2(g)$ --> $CH_3OH\ (l)$

c. $C\ (graphite) + 2\ H_2\ (g) \rightarrow CH_4\ (g)$ d. $C\ (graphite) + 6\ H_2O\ (s) \rightarrow C_6H_{12}O_6\ (s)$

9. Some cold packs use the dissolving of ammonium nitrate (shown below) to lower the temperature of the surroundings (liquid) inside the pack. Which of the following is true of this process of ammonium nitrate dissolving?

$$NH_4NO_3\ (s) \rightarrow NH_4^+\ (aq) + NO_3^-\ (aq)$$

1. The dissolving process is endothermic
2. The dissolving process is exothermic
3. The dissolving process has a negative change in entropy.
4. The dissolving process has a positive change in entropy.

a. only 1 is true b. only 2 is true c. both 1 & 4 are true d. both 2 & 3 are true

10. The enthalpy change for the thermochemical equation $2NH_3\ (g) \rightarrow N_2\ (g) + 3\ H_2\ (g)$ is +92.2 kJ. The *enthalpy of formation* of NH_3 (g) in kJ/mol must be:

a. + 92.2 b. + 41.1 c. – 92.2 d. – 41.1 e. 184.4

11. Which of the following processes would be expected to have a *negative* ΔS *value*?

a. $CaO\ (s) + CO_2\ (g) \rightarrow CaCO_3\ (s)$
b. $2\ NH_3\ (g) \rightarrow N_2\ (g) + 3\ H_2\ (g)$
c. $H_2O\ (s) \rightarrow H_2O\ (l)$

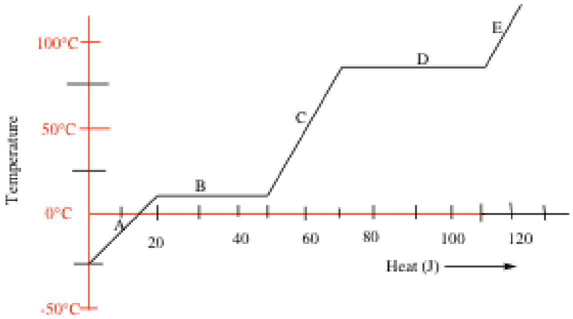
Appendix G1: Assessment, Exam 1

d. $2\ NO_2\ (g) \rightarrow 2\ NO\ (g) + O_2\ (g)$

12. Imagine you are adding heat to 200 g samples of each of the following metals, which are all at the same initial temperature of 25˚C. You want all the metals to reach the same final temperature of 100˚C. Which metal must you add **the most heat to** in order to reach this final temperature?

Metal	**Specific Heat Capacity, J/g˚C**
a. Chromium	0.447
b. Copper	0.385
c. Gold	0.129
d. Silver	0.237

The following heating curve shows the temperature change of 1.0 mol of a substance as heat is added. Use this diagram to answer the following three questions.



13. Which region corresponds to the heating of only the liquid phase?

a. Region A b. Region B c. Region C d. Region D e. Region E

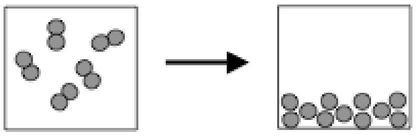
14. Moving from region E to region C is an:

a. endothermic process b. exothermic process c. both endothermic and exothermic d. cannot determine or none of the above

15. How much heat (approximately) is involved in this substance boiling (that is, changing from liquid to gas)?

a. 10 J b. 20 J c. 30 J d. 40 J

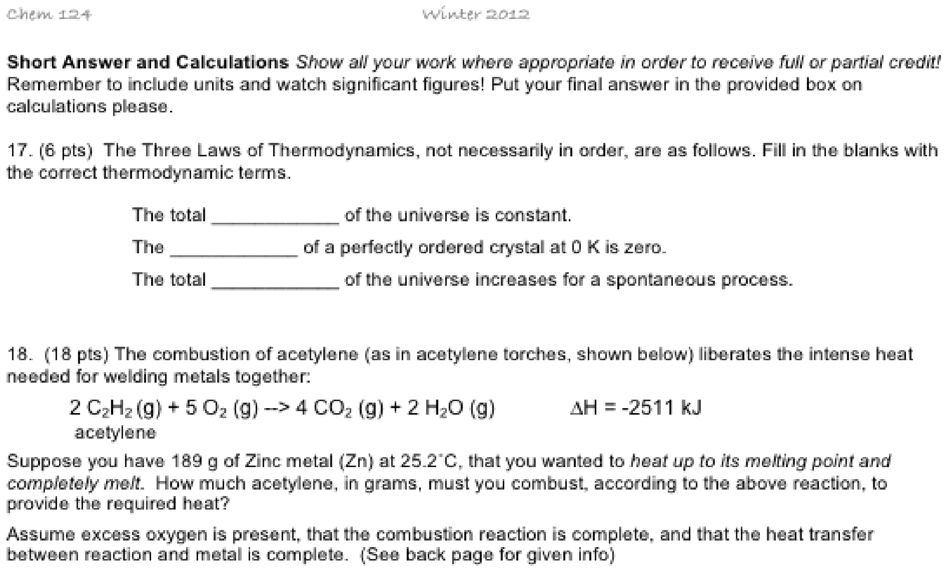
16. Consider the process shown here:



What signs would you **predict** for ΔH and ΔS for this process?

a. +ΔH, +ΔS b. –ΔH, +ΔS c. -ΔH, -ΔS d. +ΔH, -ΔS

Appendix G1: Assessment, Exam 1



Chem 124 Winter 2012

Short Answer and Calculations *Show all your work where appropriate in order to receive full or partial credit!* Remember to include units and watch significant figures! Put your final answer in the provided box on calculations please.

17. (6 pts) The Three Laws of Thermodynamics, not necessarily in order, are as follows. Fill in the blanks with the correct thermodynamic terms.

The total ____________ of the universe is constant.

The ____________ of a perfectly ordered crystal at 0 K is zero.

The total ____________ of the universe increases for a spontaneous process.

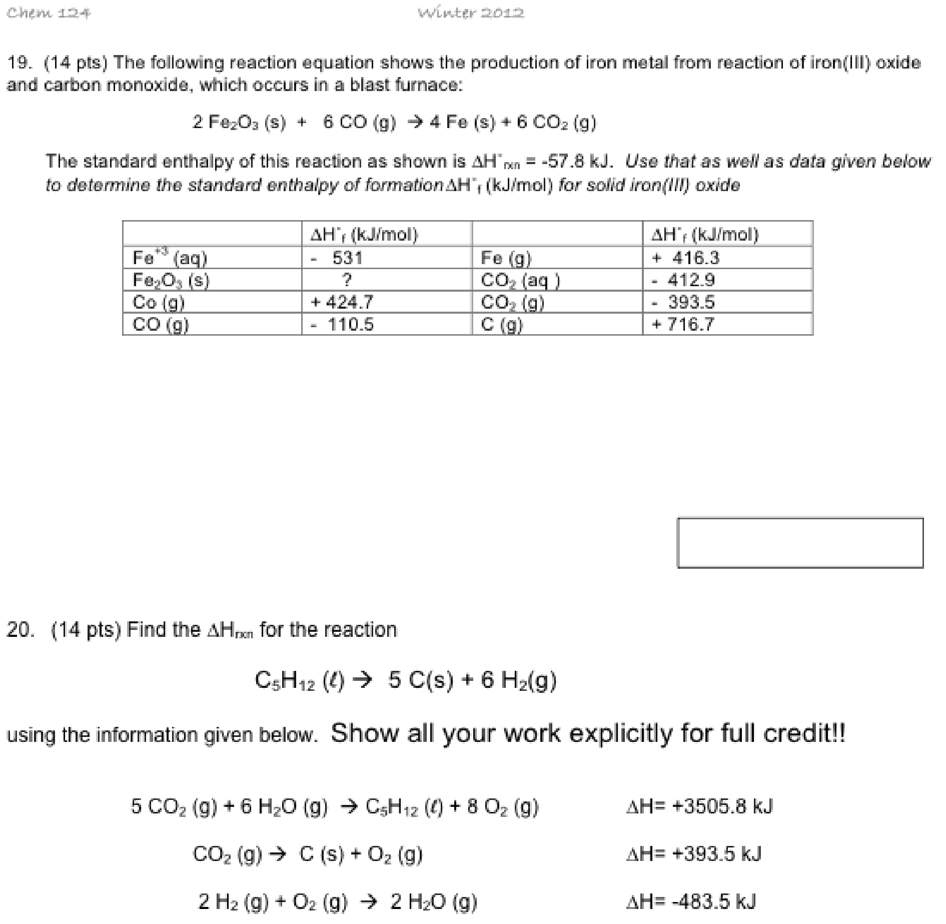
18. (18 pts) The combustion of acetylene (as in acetylene torches, shown below) liberates the intense heat needed for welding metals together:

$2\ C_2H_2\ (g) + 5\ O_2\ (g) \dashrightarrow 4\ CO_2\ (g) + 2\ H_2O\ (g)$ $\quad\Delta H = -2511$ kJ

acetylene

Suppose you have 189 g of Zinc metal (Zn) at 25.2˚C, that you wanted to *heat up to its melting point and completely melt*. How much acetylene, in grams, must you combust, according to the above reaction, to provide the required heat?

Assume excess oxygen is present, that the combustion reaction is complete, and that the heat transfer between reaction and metal is complete. (See back page for given info)



Chem 124 Winter 2012

19. (14 pts) The following reaction equation shows the production of iron metal from reaction of iron(III) oxide and carbon monoxide, which occurs in a blast furnace:

$2\ Fe_2O_3\ (s) + 6\ CO\ (g) \rightarrow 4\ Fe\ (s) + 6\ CO_2\ (g)$

The standard enthalpy of this reaction as shown is $\Delta H^\circ_{rxn} = -57.8$ kJ. *Use that as well as data given below to determine the standard enthalpy of formation* ΔH°_f (kJ/mol) *for solid iron(III) oxide*

	ΔH°_f (kJ/mol)		ΔH°_f (kJ/mol)
Fe^{+3} (aq)	- 531	Fe (g)	+ 416.3
Fe_2O_3 (s)	?	CO_2 (aq)	- 412.9
Co (g)	+ 424.7	CO_2 (g)	- 393.5
CO (g)	- 110.5	C (g)	+ 716.7

20. (14 pts) Find the ΔH_{rxn} for the reaction

$C_5H_{12}\ (\ell) \rightarrow 5\ C(s) + 6\ H_2(g)$

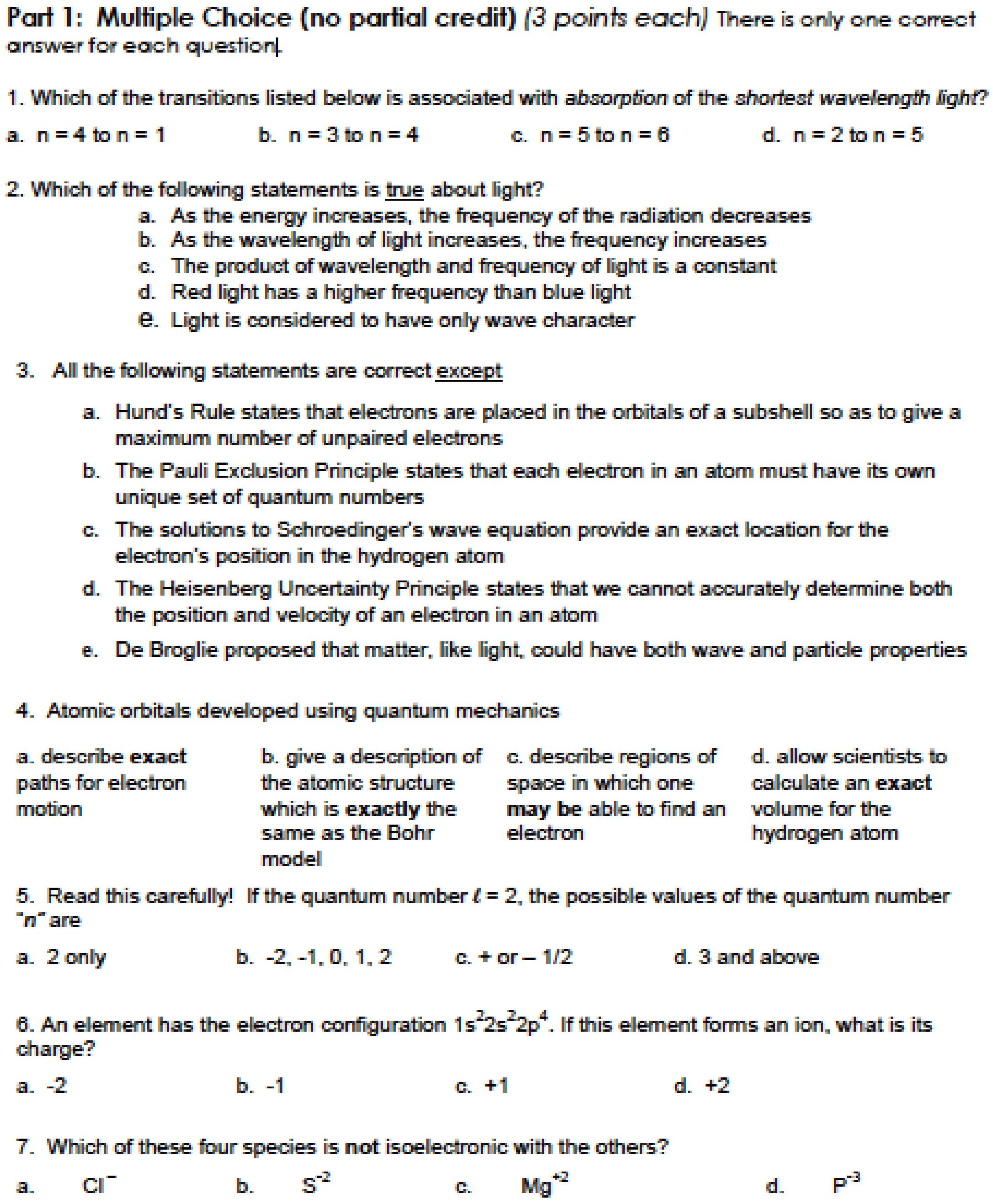
using the information given below. Show all your work explicitly for full credit!!

$5\ CO_2\ (g) + 6\ H_2O\ (g) \rightarrow C_5H_{12}\ (\ell) + 8\ O_2\ (g)$ $\quad\Delta H = +3505.8$ kJ

$CO_2\ (g) \rightarrow C\ (s) + O_2\ (g)$ $\quad\Delta H = +393.5$ kJ

$2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (g)$ $\quad\Delta H = -483.5$ kJ

Appendix G2: Assessment, Exam 2



Part 1: Multiple Choice (no partial credit) *(3 points each)* There is only one correct answer for each question.

1. Which of the transitions listed below is associated with *absorption* of the *shortest wavelength light*?

a. n = 4 to n = 1 b. n = 3 to n = 4 c. n = 5 to n = 6 d. n = 2 to n = 5

2. Which of the following statements is <u>true</u> about light?

a. As the energy increases, the frequency of the radiation decreases
b. As the wavelength of light increases, the frequency increases
c. The product of wavelength and frequency of light is a constant
d. Red light has a higher frequency than blue light
e. Light is considered to have only wave character

3. All the following statements are correct <u>except</u>

a. Hund's Rule states that electrons are placed in the orbitals of a subshell so as to give a maximum number of unpaired electrons
b. The Pauli Exclusion Principle states that each electron in an atom must have its own unique set of quantum numbers
c. The solutions to Schroedinger's wave equation provide an exact location for the electron's position in the hydrogen atom
d. The Heisenberg Uncertainty Principle states that we cannot accurately determine both the position and velocity of an electron in an atom
e. De Broglie proposed that matter, like light, could have both wave and particle properties

4. Atomic orbitals developed using quantum mechanics

a. describe **exact** paths for electron motion
b. give a description of the atomic structure which is **exactly** the same as the Bohr model
c. describe regions of space in which one **may be** able to find an electron
d. allow scientists to calculate an **exact** volume for the hydrogen atom

5. Read this carefully! If the quantum number $\ell = 2$, the possible values of the quantum number "*n*" are

a. 2 only b. -2, -1, 0, 1, 2 c. + or – 1/2 d. 3 and above

6. An element has the electron configuration $1s^2 2s^2 2p^4$. If this element forms an ion, what is its charge?

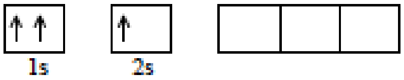
a. -2 b. -1 c. +1 d. +2

7. Which of these four species is **not** isoelectronic with the others?

a. Cl^- b. S^{-2} c. Mg^{+2} d. P^{-3}

Appendix G2: Assessment, Exam 2

8. Which rule is broken in the orbital diagram shown below?



a) Hund's Rule   b) Pauli Exclusion Principle   c) Heisenberg Uncertainty Principle   d) Aufbau Principle

9. Select the correct set of quantum numbers (n, ℓ, m_l, m_s) for one of the *highest energy electrons* (one of the last electron to fill in) in Copernicium ($_{112}Cn$)
   a. 6, 0, 0, -1/2
   b. 5, 2, 2, -1/2
   c. 6, 2, 2, -1/2
   d. 4, 3, 2, -1/2

10. Select the correct set of quantum numbers (n, ℓ, m_l, m_s) for the *first electron removed* in the formation of $_{43}Tc^{+2}$
   a. 5, 2, 0, 1/2
   b. 4, 0, 0, 1/2
   c. 5, 0, 0, 1/2
   d. 4, 2, 2, 1/2

11. Arrange indium, calcium, bismuth and lithium in order of *increasing atomic size (smallest first)*
   a. In < Ca < Bi < Li
   b. Bi < In < Ca < Li
   c. Li < Ca < In < Bi
   d. Li < Bi< Ca < In

12. Arrange fluorine, arsenic, potassium and sulfur in order of *decreasing ionization energy (highest IE 1st)*
   a. F > S > As > K
   b. S > As > F > K
   c. K > As > S > F
   d. As > S > K > F

13. Elements with ______________ first ionization energies and __________________electron affinities generally form positively charged ions (or cations). (Remember how I defined "high" electron affinity.)
   a. High, low
   b. Low, low
   c. High, high
   d. Low, high

14. Select the diamagnetic ion
   a. Mn^{+2}
   b. Co^{+3}
   c. Cu^{+1}
   d. Ti^{+4}

Appendix G2: Assessment, Exam 2

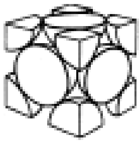
15. The chemical properties of arsenic would be predicted to be most similar to

a. $_{36}$Kr b. $_{34}$Se c. $_{31}$Ga d. $_{15}$P

16. Which of the following statements is *incorrect, or wrong*?

a. O^{-2} is larger than O b. Mg^{+2} is smaller than Ca^{+2} c. Cs^{+1} is smaller than Cs d. N^{-3} is larger than P^{-3}

17. The unit cell shown below corresponds to which type of crystal structure?



a. simple cubic b. body-centered cubic c. face-centered cubic d. none of these

18. Which of the following statements are true about **ionic bonding**?

- i. It involves sharing of valence electrons between two atoms
- ii. It involves transfer of valence electrons from one atom to another
- iii. It involves a nonmetal with high electron affinity and a metal with low ionization energy
- iv. It involves two nonmetals both with high electron affinities and ionization energies

a. i only b. ii only c. both i and iv d. both ii and iii

Part 2: Short Answer and Calculations *Show all your work where appropriate in order to receive full or partial credit!* **On calculations please put your answer in the provided box.**

19. (3 pts each, 12 pts total) Please give the abbreviated electron configuration for the following and determine whether the species is paramagnetic or diamagnetic. Be careful. There will be **no partial credit** given on the electron configurations.

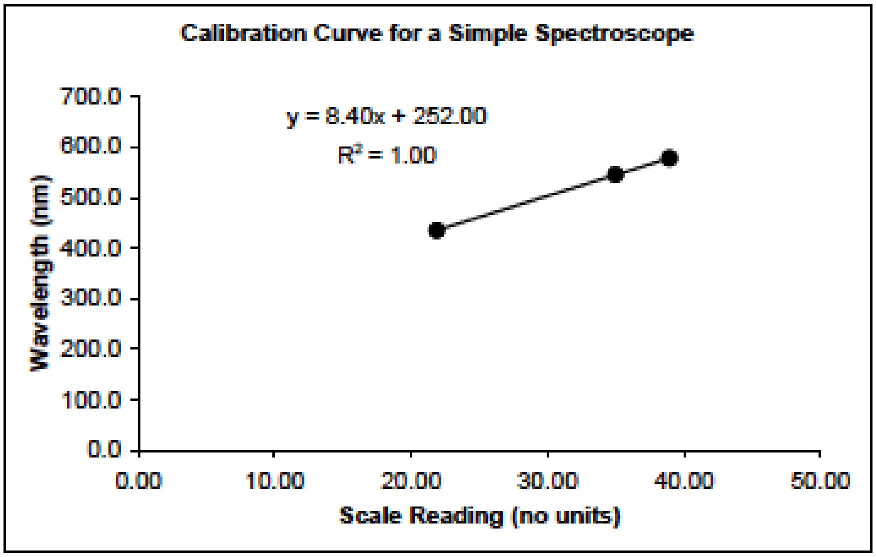
Species	**Electron Configuration**	**Paramagnetic or Diamagnetic?**
a. $_{44}Ru^{+3}$		
b. $_{26}$Fe		
c. $_{52}$Te		
d. $_{82}Pb^{+2}$		

20. (10 pts) (Don't make this problem any harder than it really is! Its really quite easy)

The human eye contains a molecule call 11-*cis*-retinal that changes shape when struck with light of sufficient energy. This change in shape triggers a series of events that results in an electrical signal being sent to the brain (and the person then seeing something!). The lowest energy of light that will cause 11-*cis*-retinal to change shape within the eye is about 184 kJ/mole of photons. Calculate the longest wavelength of light visible to the human eye, in nm.

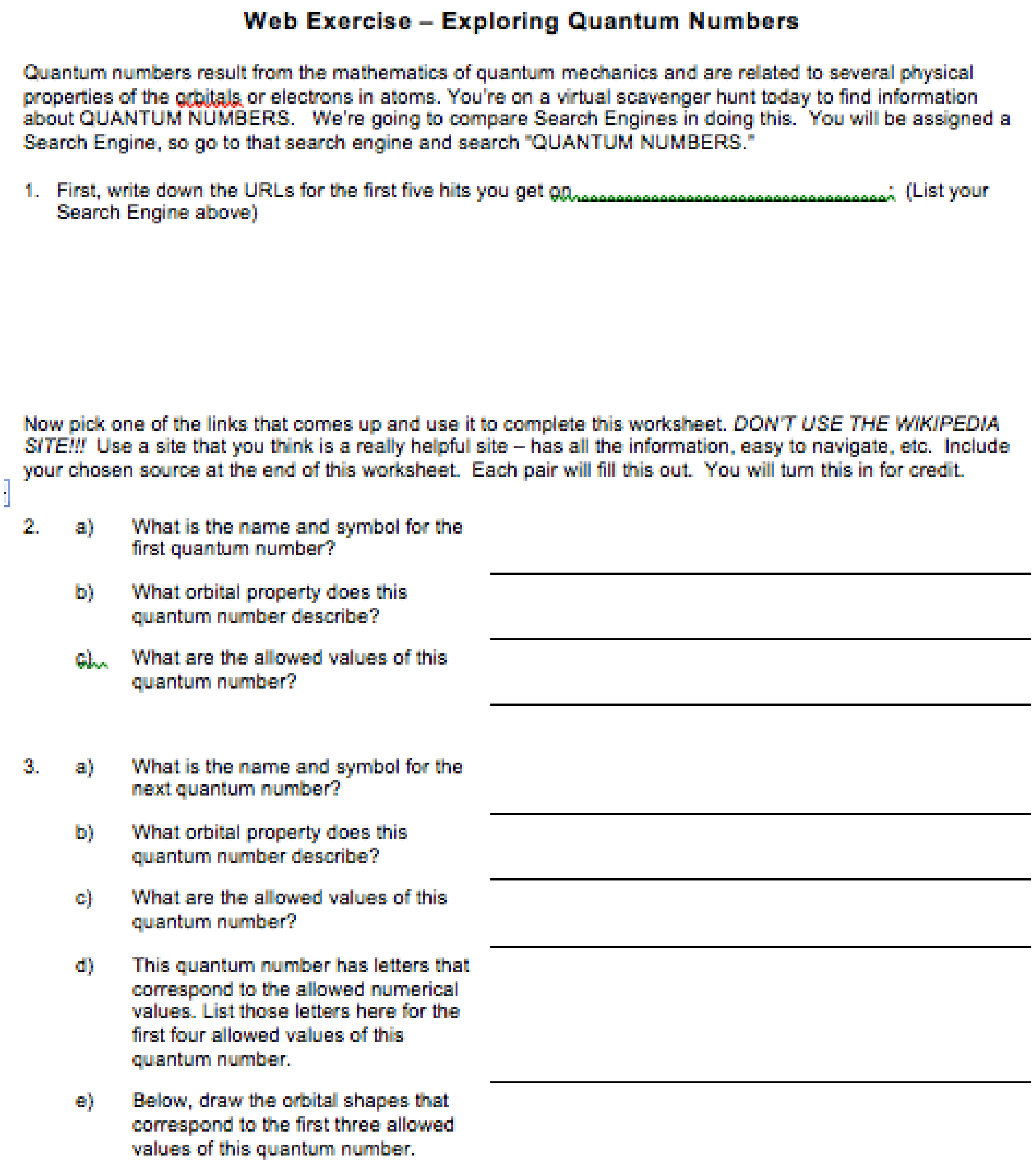
21. (10 pts) Alveoli, the tiny sacs of air in the lungs, have diameters of about 5.0×10^{-5} m. Consider an oxygen molecule, with a mass of 5.3×10^{-26} kg, trapped in one of these sacs. Calculate the uncertainty in the velocity of this oxygen molecule (in m/sec), if you estimate the uncertainty in position to be the same as the diameter of the alveoli.

22. (14 pts) A simple spectroscope was built and then calibrated using a mercury lamp. The resulting calibration curve is shown below.



You use this spectroscope to observe a *hydrogen lamp*. You observe an *emission line* to have a scale reading of 18.81 using this spectroscope. You know this emission line corresponds to an electron in hydrogen making a transition *to the n = 2 level*. What "n" level did this electron start out in?

Appendix H: Quantum Number Worksheet (Day 12)



Web Exercise – Exploring Quantum Numbers

Quantum numbers result from the mathematics of quantum mechanics and are related to several physical properties of the orbitals or electrons in atoms. You're on a virtual scavenger hunt today to find information about QUANTUM NUMBERS. We're going to compare Search Engines in doing this. You will be assigned a Search Engine, so go to that search engine and search "QUANTUM NUMBERS."

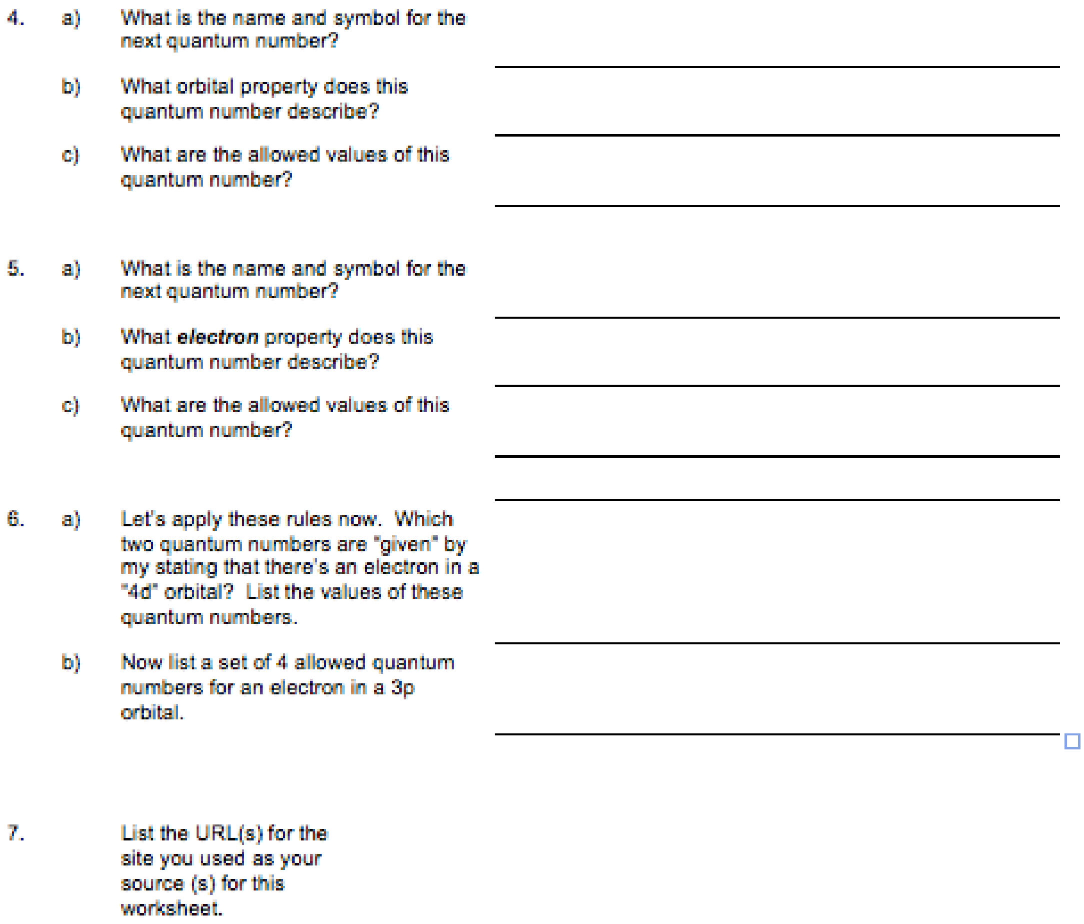
1. First, write down the URLs for the first five hits you get on ________________________________: (List your Search Engine above)

Now pick one of the links that comes up and use it to complete this worksheet. *DON'T USE THE WIKIPEDIA SITE!!!* Use a site that you think is a really helpful site – has all the information, easy to navigate, etc. Include your chosen source at the end of this worksheet. Each pair will fill this out. You will turn this in for credit.

2. a) What is the name and symbol for the first quantum number? ____________________
   b) What orbital property does this quantum number describe? ____________________
   c) What are the allowed values of this quantum number? ____________________

3. a) What is the name and symbol for the next quantum number? ____________________
   b) What orbital property does this quantum number describe? ____________________
   c) What are the allowed values of this quantum number? ____________________
   d) This quantum number has letters that correspond to the allowed numerical values. List those letters here for the first four allowed values of this quantum number. ____________________
   e) Below, draw the orbital shapes that correspond to the first three allowed values of this quantum number.

Appendix H: Quantum Number Worksheet (Day 12)



4. a) What is the name and symbol for the next quantum number?

b) What orbital property does this quantum number describe?

c) What are the allowed values of this quantum number?

5. a) What is the name and symbol for the next quantum number?

b) What ***electron*** property does this quantum number describe?

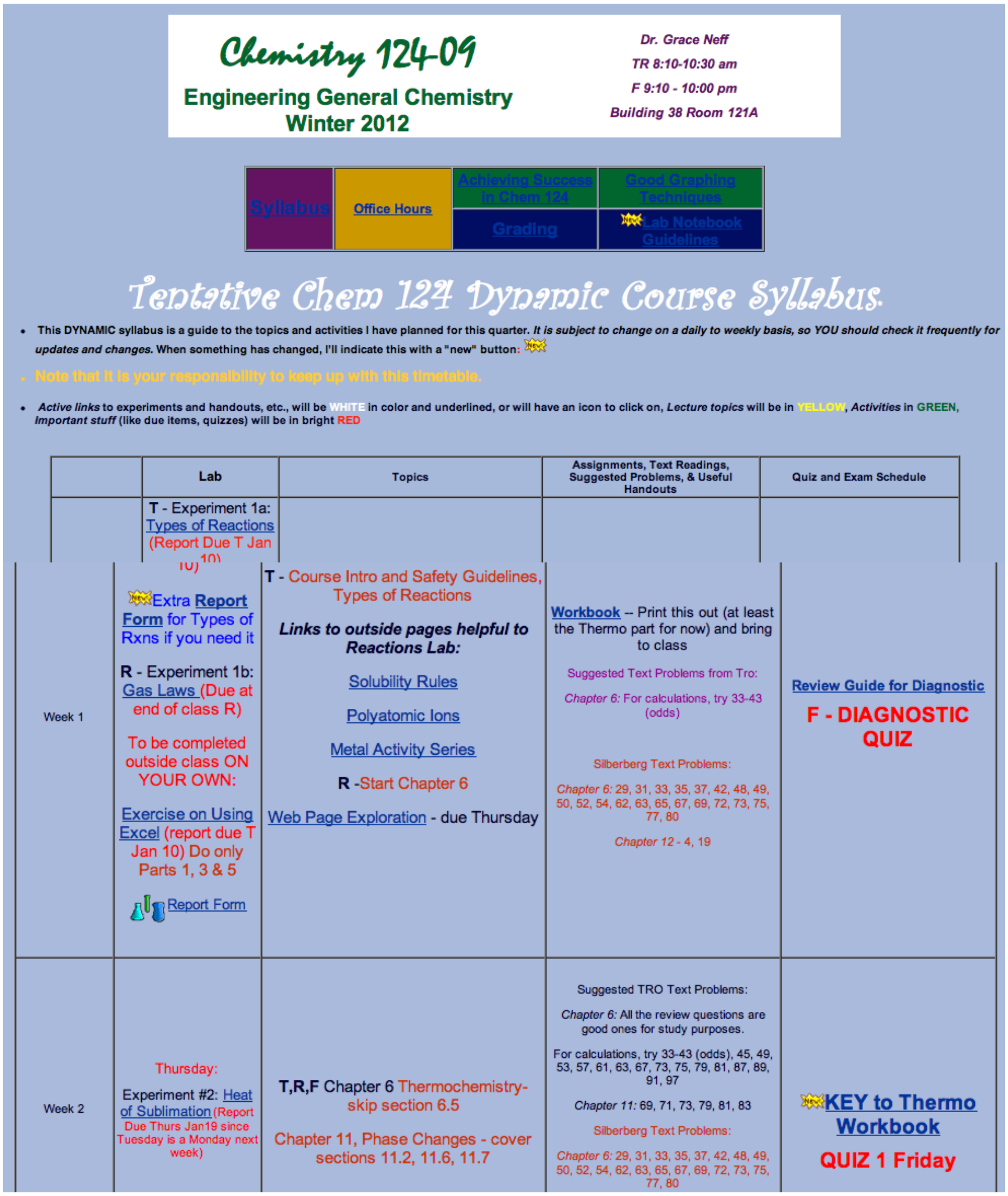
c) What are the allowed values of this quantum number?

6. a) Let's apply these rules now. Which two quantum numbers are "given" by my stating that there's an electron in a "4d" orbital? List the values of these quantum numbers.

b) Now list a set of 4 allowed quantum numbers for an electron in a 3p orbital.

7. List the URL(s) for the site you used as your source (s) for this worksheet.

Appendix J1: Dynamic Course Syllabus (Winter 2012 - Weeks 1-6)



Chemistry 124-09

Engineering General Chemistry
Winter 2012

Dr. Grace Neff
TR 8:10-10:30 am
F 9:10 - 10:00 pm
Building 38 Room 121A

Tentative Chem 124 Dynamic Course Syllabus.

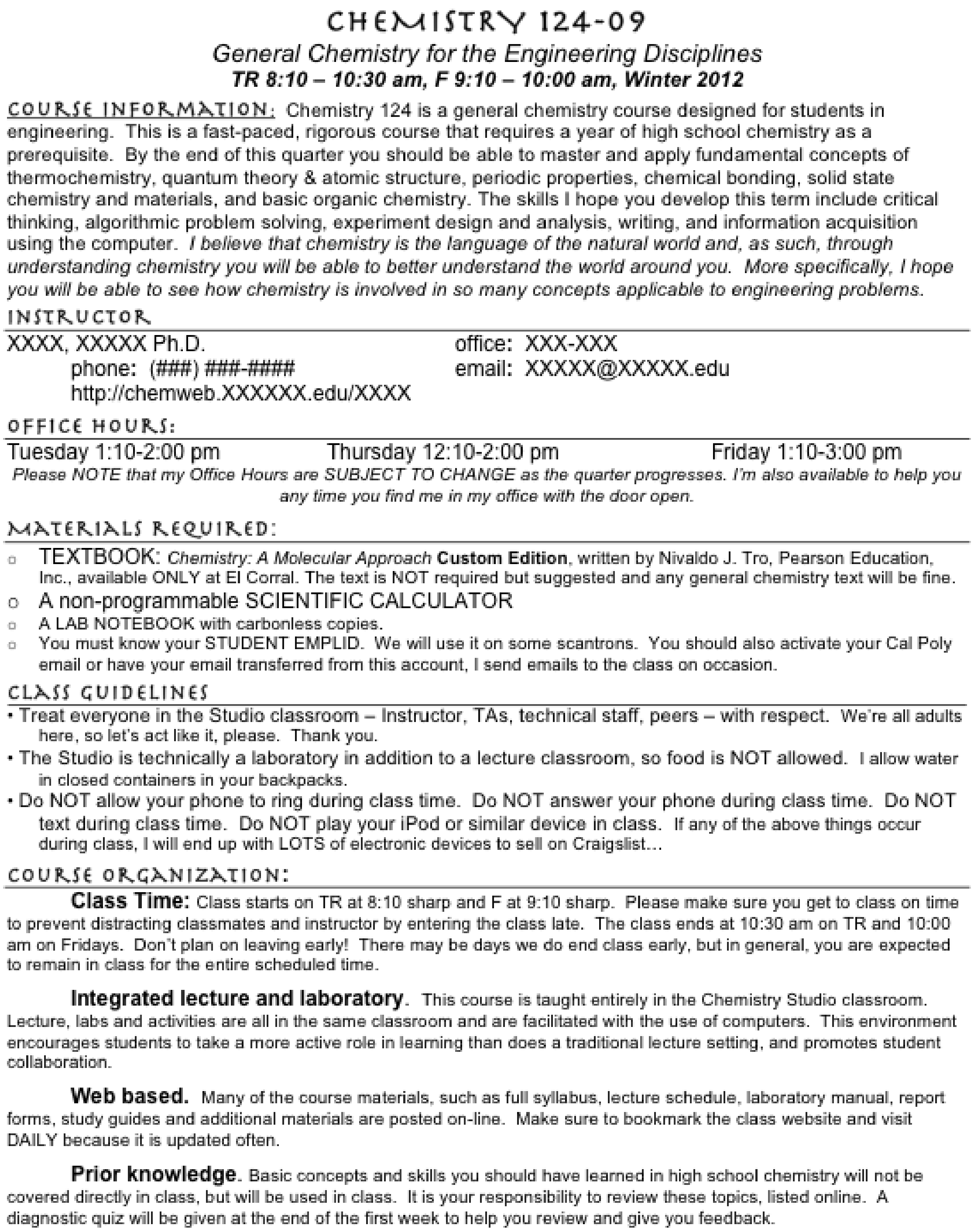
- This DYNAMIC syllabus is a guide to the topics and activities I have planned for this quarter. *It is subject to change on a daily to weekly basis, so YOU should check it frequently for updates and changes.* When something has changed, I'll indicate this with a "new" button:
- Note that it is your responsibility to keep up with this timetable.
- *Active links* to experiments and handouts, etc., will be WHITE in color and underlined, or will have an icon to click on, *Lecture topics* will be in YELLOW, *Activities* in GREEN, *Important stuff* (like due items, quizzes) will be in bright RED

	Lab	Topics	Assignments, Text Readings, Suggested Problems, & Useful Handouts	Quiz and Exam Schedule
Week 1	**T** - Experiment 1a: Types of Reactions (Report Due T Jan 10) Extra **Report Form** for Types of Rxns if you need it **R** - Experiment 1b: Gas Laws (Due at end of class R) To be completed outside class ON YOUR OWN: Exercise on Using Excel (report due T Jan 10) Do only Parts 1, 3 & 5 Report Form	**T** - Course Intro and Safety Guidelines, Types of Reactions ***Links to outside pages helpful to Reactions Lab:*** Solubility Rules Polyatomic Ions Metal Activity Series **R** -Start Chapter 6 Web Page Exploration - due Thursday	**Workbook** -- Print this out (at least the Thermo part for now) and bring to class Suggested Text Problems from Tro: *Chapter 6:* For calculations, try 33-43 (odds) Silberberg Text Problems: *Chapter 6:* 29, 31, 33, 35, 37, 42, 48, 49, 50, 52, 54, 62, 63, 65, 67, 69, 72, 73, 75, 77, 80 *Chapter 12* - 4, 19	**Review Guide for Diagnostic** **F - DIAGNOSTIC QUIZ**
Week 2	Thursday: Experiment #2: Heat of Sublimation (Report Due Thurs Jan19 since Tuesday is a Monday next week)	**T,R,F** Chapter 6 Thermochemistry-skip section 6.5 Chapter 11, Phase Changes - cover sections 11.2, 11.6, 11.7	Suggested TRO Text Problems: *Chapter 6:* All the review questions are good ones for study purposes. For calculations, try 33-43 (odds), 45, 49, 53, 57, 61, 63, 67, 73, 75, 79, 81, 87, 89, 91, 97 *Chapter 11:* 69, 71, 73, 79, 81, 83 Silberberg Text Problems: *Chapter 6:* 29, 31, 33, 35, 37, 42, 48, 49, 50, 52, 54, 62, 63, 65, 67, 69, 72, 73, 75, 77, 80	**KEY to Thermo Workbook** **QUIZ 1 Friday**

Appendix J1: Course Documentation, Dynamic Course Syllabus (Winter 2012 - Weeks 1-6)

	Report Form		Chapter 12 - 4, 19	
Week 3	Thursday: Experiment #3: Heat of Combustion (Report Due Tues Jan 24) Report Form	Tuesday is a Monday so we don't have class Chapter 17 Sections 1-7, Free Energy and Thermodynamics	Suggested TRO Text Problems: For calculations, try 33-43 (odds), 45, 49, 53, 57, 61, 63, 67, 73, 75, 79, 81, 87, 89, 91, 97 *Chapter 11:* 69, 71, 73, 79, 81, 83 *Chapter 17: 27, 29, 31, 33, 39, 41, 43, 47, 49, 51, 57, 59* Silberberg Text Problems: *Chapter 20: 2, 4, 5, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 32, 33, 35, 39, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62*	**Study Guide** **EXAM 1 next TUESDAY**
Week 4	Tuesday & Thursday: Experiment #4: Atomic Spectra (Report Due Tues Jan 31) Report Form	We will do the first part of the Atomic Spectra Lab on Tuesday - just building the spectrometer - after the exam Ch 7: Nature of the Atom: Spectroscopy, Electrons, and Quantum Numbers	Suggested TRO Text Problems: *Chapter 7:* All the review questions are good ones for study purposes. For calculations, try *38, 39, 41, 43, 45, 47, 51, 53, 55, 57, 59, 61, 63, 65, 67, 69, 71, 73, 75, 79, 81* Suggested Silberberg Text Problems: *Chapter 7: 2, 4, 5, 6, 7, 9, 11, 13, 14, 16, 20, 22, 23, 25, 27, 29, 31, 34*	**EXAM 1 TUESDAY at beginning of class** Brief History of Quantum Mechanics (YouTube Video)- check it out! Quantum Mechanics History continued - Atomic Structure explained **QUIZ 2 Friday will be take home!**
Week 5	Web Exercises on Tuesday - yes on Quantum Numbers	Ch 7: Nature of the Atom: Quantum Numbers	Suggested TRO Text Problems: *Chapter 7: 38, 39, 41, 43, 45, 47, 51, 53, 55, 57, 59, 61, 63, 65, 67, 69, 71, 73, 75, 79, 81*	
	Thursday: Experiment #5: "Dry" Lab - Periodic Properties (Report Due before you leave class R) **Summary Form**	Ch. 8 Electron Configurations, Periodic Properties - we have now finished Ch 8! ***Periodic Table***	*Chapter 8: All the review questions are good for study purposes, also try 43-75 (odds), 79-89 (odds)* Suggested Silberberg Text Problems: *Chapter 7: 37, 39, 41, 47, 48, 49, 51, 53, 55, 57, 59, 65, 66, 69, 70, 71, 81* *Chapter 8: 6, 9, 11, 13, 16, 18, 20, 21, 23, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 46, 48, 50, 53, 55, 57, 59, 61, 62, 64, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86,*	**Simulation for Models of Hydrogen Atom** **QUIZ 3 Friday** **KEY to Ch 7 & 8 Workbook**
Week 6	Tuesday & Thursday: Experiment #6: Solid State Modeling (Report Due Tues Feb 14) **Report Form** print out and fill in in pencil, 1 per pair	Ch 9: Bonding: Metallic, Ionic, and Covalent Ch 11: Intro to Solid State Structures, Metallic Solids, Ionic Solids, Lattice Energy ***Crystal Structure Tutorial & Animations*** ***Tutorial on Unit Cells & Metallic Solids***	Ch 9, Section 2 to start Ch 11, Section 10 - 12 Solid State Structures For problems, see in-class worksheets or workbook! *Suggested TRO Text Problems:* *Chapter 11: 95-117 (odds), 131, 133, 137* Suggested Silberberg Text Problems: *Chapter 9: 1, 4, 6, 8, 10, 12, 14, 20, 22, 24, 26, 28, 30, 33* *Chapter 12: 75, 76, 77, 78, 83, 84, 85, 86, 88,90*	**Study Guide** **EXAM 2 Friday**

Appendix J2: Course Documentation, Syllabus and Course Information



CHEMISTRY 124-09

General Chemistry for the Engineering Disciplines

TR 8:10 – 10:30 am, F 9:10 – 10:00 am, Winter 2012

COURSE INFORMATION: Chemistry 124 is a general chemistry course designed for students in engineering. This is a fast-paced, rigorous course that requires a year of high school chemistry as a prerequisite. By the end of this quarter you should be able to master and apply fundamental concepts of thermochemistry, quantum theory & atomic structure, periodic properties, chemical bonding, solid state chemistry and materials, and basic organic chemistry. The skills I hope you develop this term include critical thinking, algorithmic problem solving, experiment design and analysis, writing, and information acquisition using the computer. *I believe that chemistry is the language of the natural world and, as such, through understanding chemistry you will be able to better understand the world around you. More specifically, I hope you will be able to see how chemistry is involved in so many concepts applicable to engineering problems.*

INSTRUCTOR

XXXX, XXXXX Ph.D.	office: XXX-XXX
phone: (###) ###-#####	email: XXXXX@XXXXX.edu
http://chemweb.XXXXXX.edu/XXXX	

OFFICE HOURS:

Tuesday 1:10-2:00 pm Thursday 12:10-2:00 pm Friday 1:10-3:00 pm

Please NOTE that my Office Hours are SUBJECT TO CHANGE as the quarter progresses. I'm also available to help you any time you find me in my office with the door open.

MATERIALS REQUIRED:

- TEXTBOOK: *Chemistry: A Molecular Approach* **Custom Edition**, written by Nivaldo J. Tro, Pearson Education, Inc., available ONLY at El Corral. The text is NOT required but suggested and any general chemistry text will be fine.
- A non-programmable SCIENTIFIC CALCULATOR
- A LAB NOTEBOOK with carbonless copies.
- You must know your STUDENT EMPLID. We will use it on some scantrons. You should also activate your Cal Poly email or have your email transferred from this account, I send emails to the class on occasion.

CLASS GUIDELINES

- Treat everyone in the Studio classroom – Instructor, TAs, technical staff, peers – with respect. We're all adults here, so let's act like it, please. Thank you.
- The Studio is technically a laboratory in addition to a lecture classroom, so food is NOT allowed. I allow water in closed containers in your backpacks.
- Do NOT allow your phone to ring during class time. Do NOT answer your phone during class time. Do NOT text during class time. Do NOT play your iPod or similar device in class. If any of the above things occur during class, I will end up with LOTS of electronic devices to sell on Craigslist…

COURSE ORGANIZATION:

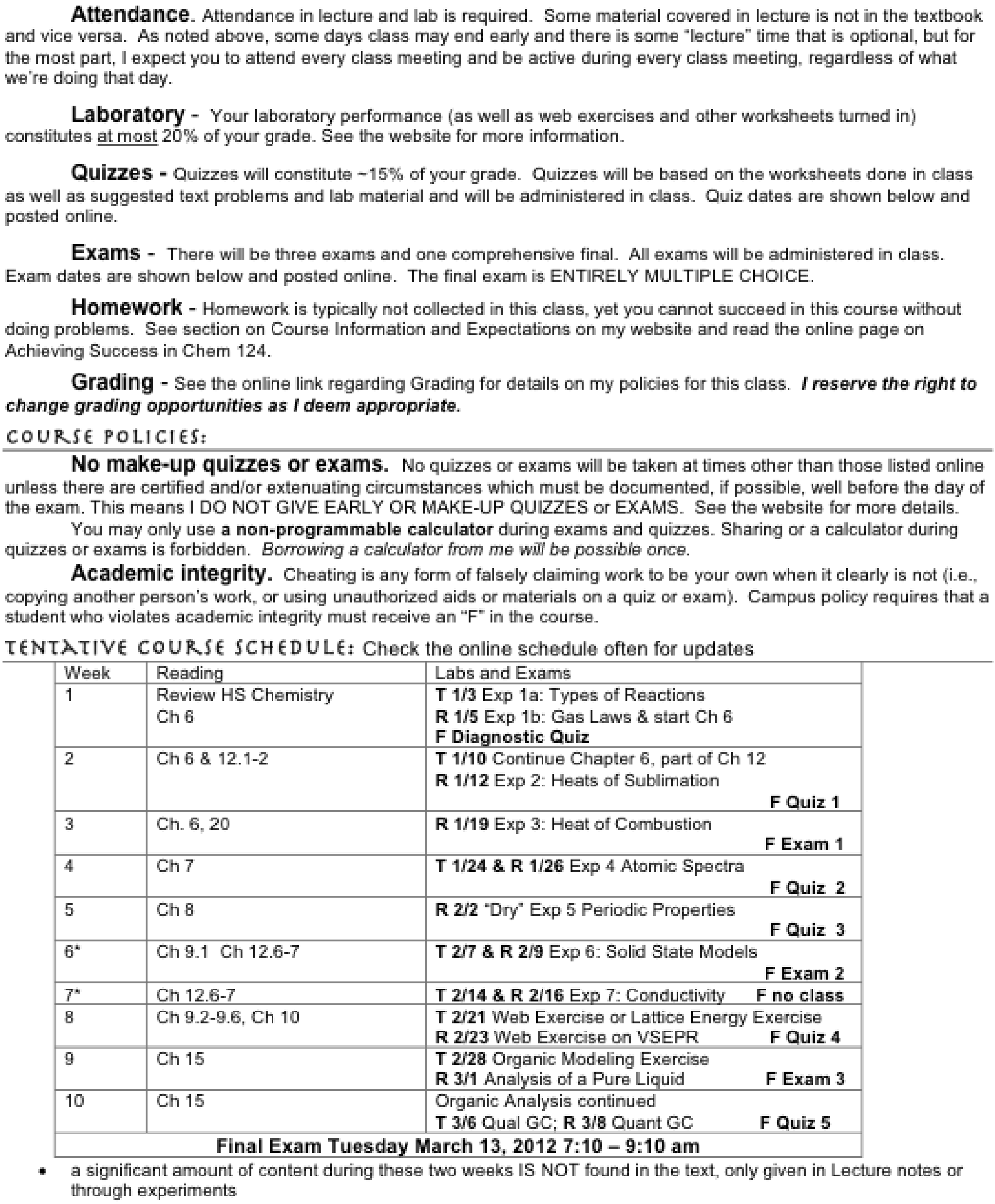
Class Time: Class starts on TR at 8:10 sharp and F at 9:10 sharp. Please make sure you get to class on time to prevent distracting classmates and instructor by entering the class late. The class ends at 10:30 am on TR and 10:00 am on Fridays. Don't plan on leaving early! There may be days we do end class early, but in general, you are expected to remain in class for the entire scheduled time.

Integrated lecture and laboratory. This course is taught entirely in the Chemistry Studio classroom. Lecture, labs and activities are all in the same classroom and are facilitated with the use of computers. This environment encourages students to take a more active role in learning than does a traditional lecture setting, and promotes student collaboration.

Web based. Many of the course materials, such as full syllabus, lecture schedule, laboratory manual, report forms, study guides and additional materials are posted on-line. Make sure to bookmark the class website and visit DAILY because it is updated often.

Prior knowledge. Basic concepts and skills you should have learned in high school chemistry will not be covered directly in class, but will be used in class. It is your responsibility to review these topics, listed online. A diagnostic quiz will be given at the end of the first week to help you review and give you feedback.

Appendix J2: Course Documentation, Syllabus and Course Information



Attendance. Attendance in lecture and lab is required. Some material covered in lecture is not in the textbook and vice versa. As noted above, some days class may end early and there is some "lecture" time that is optional, but for the most part, I expect you to attend every class meeting and be active during every class meeting, regardless of what we're doing that day.

Laboratory - Your laboratory performance (as well as web exercises and other worksheets turned in) constitutes at most 20% of your grade. See the website for more information.

Quizzes - Quizzes will constitute ~15% of your grade. Quizzes will be based on the worksheets done in class as well as suggested text problems and lab material and will be administered in class. Quiz dates are shown below and posted online.

Exams - There will be three exams and one comprehensive final. All exams will be administered in class. Exam dates are shown below and posted online. The final exam is ENTIRELY MULTIPLE CHOICE.

Homework - Homework is typically not collected in this class, yet you cannot succeed in this course without doing problems. See section on Course Information and Expectations on my website and read the online page on Achieving Success in Chem 124.

Grading - See the online link regarding Grading for details on my policies for this class. ***I reserve the right to change grading opportunities as I deem appropriate.***

COURSE POLICIES:

No make-up quizzes or exams. No quizzes or exams will be taken at times other than those listed online unless there are certified and/or extenuating circumstances which must be documented, if possible, well before the day of the exam. This means I DO NOT GIVE EARLY OR MAKE-UP QUIZZES or EXAMS. See the website for more details.

You may only use **a non-programmable calculator** during exams and quizzes. Sharing or a calculator during quizzes or exams is forbidden. *Borrowing a calculator from me will be possible once.*

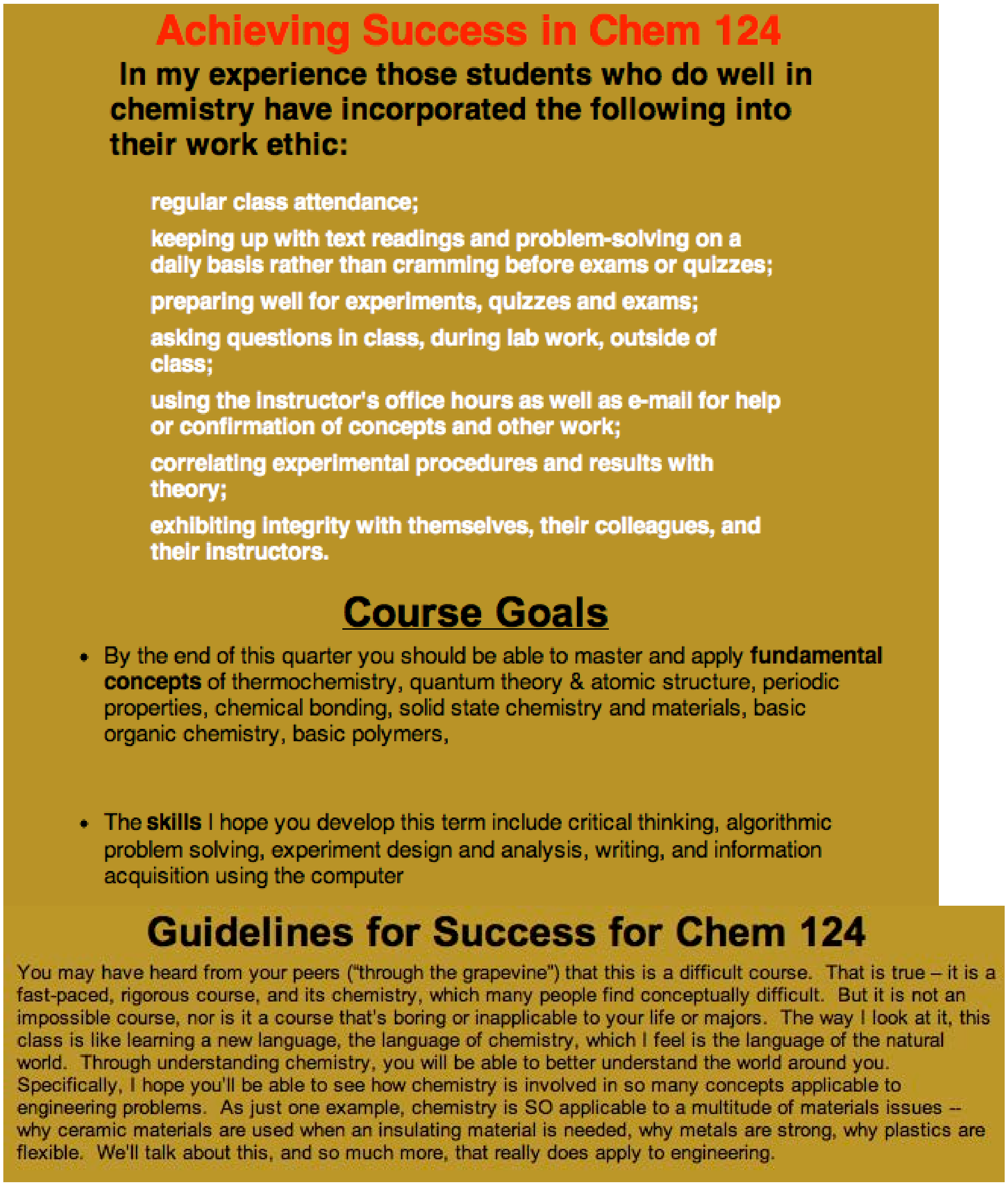
Academic integrity. Cheating is any form of falsely claiming work to be your own when it clearly is not (i.e., copying another person's work, or using unauthorized aids or materials on a quiz or exam). Campus policy requires that a student who violates academic integrity must receive an "F" in the course.

TENTATIVE COURSE SCHEDULE: Check the online schedule often for updates

Week	Reading	Labs and Exams
1	Review HS Chemistry Ch 6	**T 1/3** Exp 1a: Types of Reactions **R 1/5** Exp 1b: Gas Laws & start Ch 6 **F Diagnostic Quiz**
2	Ch 6 & 12.1-2	**T 1/10** Continue Chapter 6, part of Ch 12 **R 1/12** Exp 2: Heats of Sublimation **F Quiz 1**
3	Ch. 6, 20	**R 1/19** Exp 3: Heat of Combustion **F Exam 1**
4	Ch 7	**T 1/24 & R 1/26** Exp 4 Atomic Spectra **F Quiz 2**
5	Ch 8	**R 2/2** "Dry" Exp 5 Periodic Properties **F Quiz 3**
6*	Ch 9.1 Ch 12.6-7	**T 2/7 & R 2/9** Exp 6: Solid State Models **F Exam 2**
7*	Ch 12.6-7	**T 2/14 & R 2/16** Exp 7: Conductivity **F no class**
8	Ch 9.2-9.6, Ch 10	**T 2/21** Web Exercise or Lattice Energy Exercise **R 2/23** Web Exercise on VSEPR **F Quiz 4**
9	Ch 15	**T 2/28** Organic Modeling Exercise **R 3/1** Analysis of a Pure Liquid **F Exam 3**
10	Ch 15	Organic Analysis continued **T 3/6** Qual GC; **R 3/8** Quant GC **F Quiz 5**
Final Exam Tuesday March 13, 2012 7:10 – 9:10 am		

- a significant amount of content during these two weeks IS NOT found in the text, only given in Lecture notes or through experiments

Appendix J3: Course Documentation, Guide to Achieving Success in Chem 124



Achieving Success in Chem 124

In my experience those students who do well in chemistry have incorporated the following into their work ethic:

regular class attendance;

keeping up with text readings and problem-solving on a daily basis rather than cramming before exams or quizzes;

preparing well for experiments, quizzes and exams;

asking questions in class, during lab work, outside of class;

using the instructor's office hours as well as e-mail for help or confirmation of concepts and other work;

correlating experimental procedures and results with theory;

exhibiting integrity with themselves, their colleagues, and their instructors.

Course Goals

- By the end of this quarter you should be able to master and apply **fundamental concepts** of thermochemistry, quantum theory & atomic structure, periodic properties, chemical bonding, solid state chemistry and materials, basic organic chemistry, basic polymers,

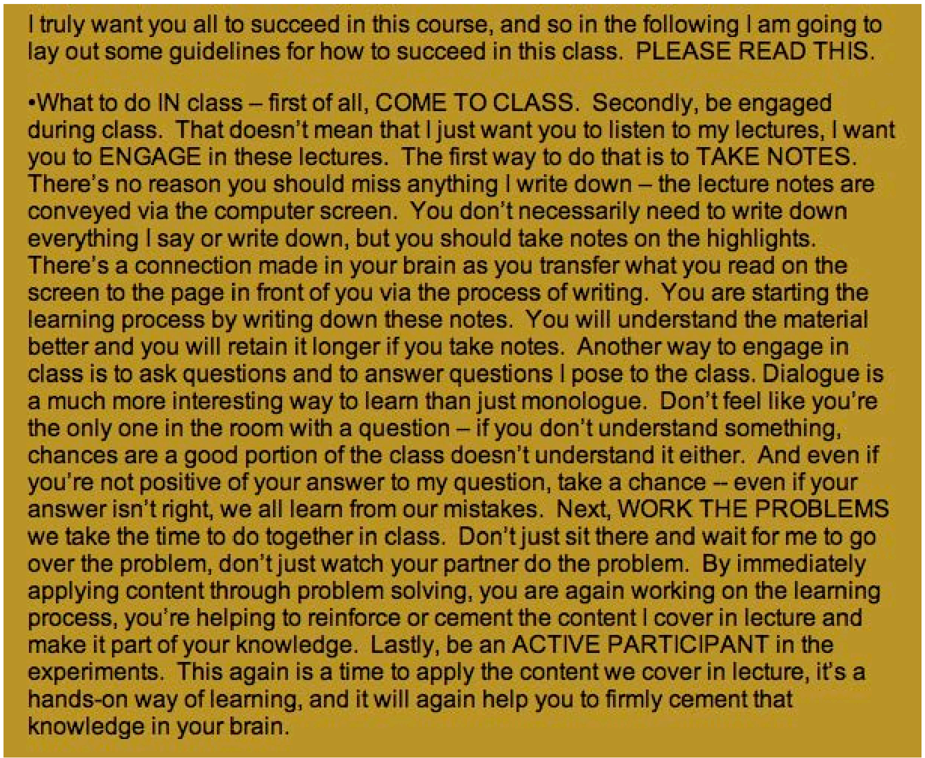
- The **skills** I hope you develop this term include critical thinking, algorithmic problem solving, experiment design and analysis, writing, and information acquisition using the computer

Guidelines for Success for Chem 124

You may have heard from your peers ("through the grapevine") that this is a difficult course. That is true – it is a fast-paced, rigorous course, and its chemistry, which many people find conceptually difficult. But it is not an impossible course, nor is it a course that's boring or inapplicable to your life or majors. The way I look at it, this class is like learning a new language, the language of chemistry, which I feel is the language of the natural world. Through understanding chemistry, you will be able to better understand the world around you. Specifically, I hope you'll be able to see how chemistry is involved in so many concepts applicable to engineering problems. As just one example, chemistry is SO applicable to a multitude of materials issues -- why ceramic materials are used when an insulating material is needed, why metals are strong, why plastics are flexible. We'll talk about this, and so much more, that really does apply to engineering.

Appendix J3: Course Documentation, Guide to Achieving Success in Chem 124

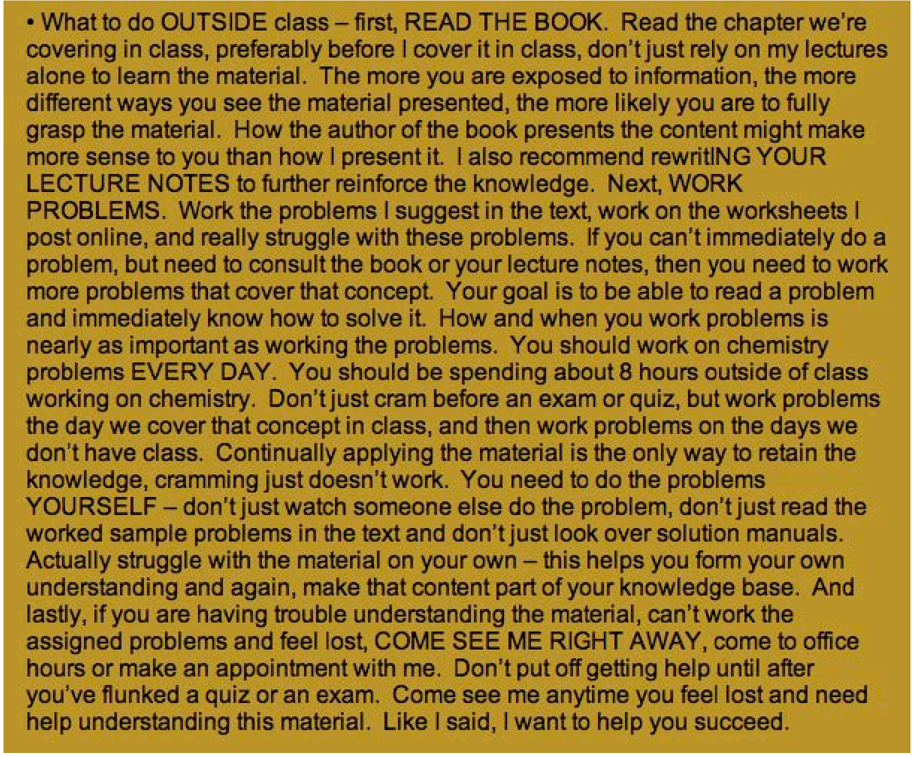
Section A



I truly want you all to succeed in this course, and so in the following I am going to lay out some guidelines for how to succeed in this class. PLEASE READ THIS.

•What to do IN class – first of all, COME TO CLASS. Secondly, be engaged during class. That doesn't mean that I just want you to listen to my lectures, I want you to ENGAGE in these lectures. The first way to do that is to TAKE NOTES. There's no reason you should miss anything I write down – the lecture notes are conveyed via the computer screen. You don't necessarily need to write down everything I say or write down, but you should take notes on the highlights. There's a connection made in your brain as you transfer what you read on the screen to the page in front of you via the process of writing. You are starting the learning process by writing down these notes. You will understand the material better and you will retain it longer if you take notes. Another way to engage in class is to ask questions and to answer questions I pose to the class. Dialogue is a much more interesting way to learn than just monologue. Don't feel like you're the only one in the room with a question – if you don't understand something, chances are a good portion of the class doesn't understand it either. And even if you're not positive of your answer to my question, take a chance -- even if your answer isn't right, we all learn from our mistakes. Next, WORK THE PROBLEMS we take the time to do together in class. Don't just sit there and wait for me to go over the problem, don't just watch your partner do the problem. By immediately applying content through problem solving, you are again working on the learning process, you're helping to reinforce or cement the content I cover in lecture and make it part of your knowledge. Lastly, be an ACTIVE PARTICIPANT in the experiments. This again is a time to apply the content we cover in lecture, it's a hands-on way of learning, and it will again help you to firmly cement that knowledge in your brain.

Section B



• What to do OUTSIDE class – first, READ THE BOOK. Read the chapter we're covering in class, preferably before I cover it in class, don't just rely on my lectures alone to learn the material. The more you are exposed to information, the more different ways you see the material presented, the more likely you are to fully grasp the material. How the author of the book presents the content might make more sense to you than how I present it. I also recommend rewritING YOUR LECTURE NOTES to further reinforce the knowledge. Next, WORK PROBLEMS. Work the problems I suggest in the text, work on the worksheets I post online, and really struggle with these problems. If you can't immediately do a problem, but need to consult the book or your lecture notes, then you need to work more problems that cover that concept. Your goal is to be able to read a problem and immediately know how to solve it. How and when you work problems is nearly as important as working the problems. You should work on chemistry problems EVERY DAY. You should be spending about 8 hours outside of class working on chemistry. Don't just cram before an exam or quiz, but work problems the day we cover that concept in class, and then work problems on the days we don't have class. Continually applying the material is the only way to retain the knowledge, cramming just doesn't work. You need to do the problems YOURSELF – don't just watch someone else do the problem, don't just read the worked sample problems in the text and don't just look over solution manuals. Actually struggle with the material on your own – this helps you form your own understanding and again, make that content part of your knowledge base. And lastly, if you are having trouble understanding the material, can't work the assigned problems and feel lost, COME SEE ME RIGHT AWAY, come to office hours or make an appointment with me. Don't put off getting help until after you've flunked a quiz or an exam. Come see me anytime you feel lost and need help understanding this material. Like I said, I want to help you succeed.

Appendix F: Transcript of Key Segments of Professor Discourse in Day 1 Introduction to the Course (Segment J6-A1)

[Theme of admin lecture: Don’t cram. Need to seek help as soon as possible.]
Segment J6-A1 10:55:52
leaving it til the last week before the final isn’t going to work
cramming before an exam or a test
final exam is comprehensive
so you need to be able to retain the material
it better if you do a few problems everyday
particularly if you go back
after we have covered something in class
you go back
and you study
a little bit by going over your notes
maybe read the text
clarify some things
that didn’t make sense to you
and then do some problems to apply what we worked on
that’s going to cement that knowledge into your brain
after you’ve learned it or heard it in class
and
I also think
it's pretty much imperative
that you take notes in class
I really wasn’t paying attention yesterday
to see if people were taking notes
but it always surprises me
when I notice that
people don’t take notes
to me
there’s a connection
that needs to be made
between what you hear
and what goes into your brain
and when you write things down
I think you do make some connections in your brain
that help you solidify that stuff
some people will argue that they’re auditory learners
visual learners
or that they can’t keep up with me
regardless of what kind of learner you are
it really helps if you take notes
it engages you in the class and in the material
and helps
make it
more real to you
and helps cement it in your brain

Appendix K: Transcript of Key Segments of Professor Discourse in Day 3 Introduction to the Course (Segment J6-A1)

in my opinion
um
if I do go too fast on the notes
slow me down
that’s one of the most common complaints
on my evaluations is that I talk too fast
and I write too fast
it’s a lot easier to write on a piece of paper like this
as it is to write on a whiteboard or chalkboard
so I do normally do go a little faster
than I would in a normal lecture class
um
I’ve also had a lot of complaints
and I was thinking about it yesterday
as I was writing notes
that my notes are kinda messy
and that’s something I’m gonna work on too
ok
and please
give me feedback
especially about going too fast
but also about whether
I need to be a little bit more organized
I’m already thinking about that in my head
I’m going to try it
to help you guys
um
in addition to be
engaged in class
in terms of taking notes
work on the problems
when we break
to work on the problems
don’t go out and start surfing the web
and start playing
computer games
or checking facebook
or what not
work on those problems
because that’s an opportunity
to talk to the people at your table
to help understand what’s going on
and to get help
because we’re walking around

Appendix K: Transcript of Key Segments of Professor Discourse in Day 3 Introduction to the Course (Segment J6-A1)

to help you with the problems
and also fully engage in the experiments
because many of them
in fact all of them
apply what we are talking about in lecture very well
so they should also help you cement
the knowledge
don’t let one person in your pair
or trio
be the only person who always does the lab
you should all be in there
doing stuff
not just sitting back and watching other people do stuff
you guys are engineers
so you like to work with your hands
so getting there and
and
sharing the responsibility of doing the experiment
it's going to help you
particularly the ones who are in trios
don’t just sit back and watch the other too people
[9:01] doing stuff
ok
and I think that’s all I’m gonna
say this morning
the quiz in 20 questions long