Use and Analysis of 5E Inquiry Activities in Online General Chemistry Courses

John Ray Kiser

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USE AND ANALYSIS OF 5E INQUIRY ACTIVITIES IN ONLINE GENERAL CHEMISTRY COURSES

by

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DEDICATION

This dissertation is dedicated to the inspiring science and math teachers I have been a student under at Glen Alpine Elementary School, Table Rock Middle School, Freedom High School, Western Piedmont Community College, and Furman University. This dissertation is also dedicated my wonderful coworkers at Western Piedmont Community College, McDowell Technical Community College, Catawba Valley Community College, Isothermal Communication College, and the North Carolina Science Olympiad. You all have inspired me to become an excellent science teacher and teacher leader. My guiding principles have been that the one who sows sparingly will reap sparingly and the one who sows generously will also reap generously (2 Corinthians 9:6). One plants the seeds, another waters the seeds, but GOD makes the seeds grow (1 Corinthians 3:6). I am thankful for those who have generously planted and watered the seeds in my life. It is my hope that I am able to generously plant and water seeds for future generations of scientists, science teachers, and teacher-leaders.
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ABSTRACT

This action research dissertation provides an overview of inquiry-based learning in online general chemistry course. Due to the covid-19 pandemic, many science courses have been converted to an online format. In order to increase student learning and attitudes in online chemistry class, two inquiry-based learning activities were developed and implemented. The results on student learning and attitudes were measured by monitoring discussion forum posts, a student survey, and an assessment test. Results show that students had positive results in both learning and attitudes. Furthermore, the researcher’s understanding of inquiry and ability to implement inquiry learning were studied by use of a reflection journal and observation rubrics.

Keywords: Inquiry-based learning, 5E cycle, online chemistry course
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LIST OF ABBREVIATIONS

ACS ................................................................................ American Chemical Society
CER .............................................................................. Claim, Evidence, and Reasoning
CRP ................................................................................. Culturally Responsive Pedagogy
EQUIP ............................................................................ Electronic Quality of Inquiry Protocol
NRC ................................................................................ National Research Council
NSF ................................................................................ National Science Foundation
POGIL .............................................................................. Process Oriented Guided Inquiry Learning
RTOP ............................................................................... Reformed Teaching Observation Protocol
CHAPTER 1
INTRODUCTION

I am currently a chemistry instructor at a rural community college in western North Carolina. I am also a proud graduate of a community college in western North Carolina. It was during my attendance at a community college that I discovered a passion for personal study of chemistry and tutoring and teaching chemistry to my classmates. After I graduated from the community college, I was able to transfer to a private liberal arts university where I completed my Bachelor and Master of Science degrees in chemistry. As a student, I was comfortable with and satisfied with the traditional lecture method of instruction. I felt that the core ideas of chemistry could be effectively taught by an instructor and learned by students by using a traditional lecture.

After graduation with my master’s degree, I began teaching part-time at a community college as I determined the next steps in my professional career. That temporary part time job became 15-year teaching career in the North Carolina Community College System. As a teacher, at first I was very similar to most of my former instructors: mainly relying on the lecture method to convey information and assuming that students would learn core ideas of chemistry by listening to a lecture. While my lectures might have been long, I was careful to present the material in smaller amounts in a logical, sequential manner. In my lectures, I knew the core ideas that I needed to convey to students, and I believed I conveyed that material effectively. When I
facilitated group work activities in the classroom or laboratory, I felt that I could keep most groups on task, and I could help most groups finish in a timely manner.

However, I began to recognize that there were shortcomings in my teaching. Some students were comfortable with a traditional lecture method, but other students did not seem to learn well in the traditional lecture format. As I attended professional conferences, read teaching journals, and began this Ed. D. program, I developed an interest in using more interactive and inquiry-based learning activities in my courses. I also realized that I struggled in teaching the wide variety and diversity of students whom I encountered in my courses. Some students had never had a previous chemistry course and found the traditional lecture format and amount of course material overwhelming and intimidating. Some students were traditionally college-aged, some were returning to school for the first time in many years, and some were dual-enrolled high school students. I especially noticed that some of my dual-enrolled high school students struggled with the chemistry course material. While I had a diversity of racial and ethnic groups in my classes, a traditional lecture approach did not seem to be an effective teaching method for students of diverse racial and ethnic groups. I wanted to find an effective method to effectively teach a variety of students from a variety of backgrounds. Finally, there has been a long emphasis to teach chemistry online for students who do not have the time to attend a traditional, seated in-person course. While I have had some experience teaching in hybrid formats, where part of the class was completed in an in-person format and some in an online format, most online activities involved students watching a lecture and taking notes or completing review problems individually. I wanted to learn and develop a more effective method for teaching chemistry online.
The spring semester of 2020 presented a unique challenge that has caused me to rethink my methods of instruction. The COVID-19 pandemic resulted in a sudden shift for all my classes, from seated, in-person teaching and learning to asynchronous online teaching and learning. Many of the curriculum and instruction strategies I had used in a seated, in-person class did not translate to an effective online learning experience for students enrolled in my classes. I noticed students taking hours to complete assignments based on online lectures; those similar lectures and assignments would have taken much less time in the seated classroom. I realized that my online students were struggling to learn the course material even more than in a seated classroom. Long hours of watching videos and completing online homework was not enough for me to be an effective online instructor to all my students.

Among the various chemistry courses for which I am the instructor and that were suddenly shifted online during the COVID-19 pandemic, the main course that serve the most diverse students is the introductory level General Chemistry 1, or CHM 151. CHM 151 is a course designed for students who intend to transfer to a four-year university and obtain a science-related degree, such as engineering, environmental science, or a health science. In addition to science majors, CHM 151 is also used to meet the dual-enrolled high school students’ high school chemistry or physical science credit. The students who enroll in CHM 151 can also have a variety of previous science and math courses. Students may have not taken any previous college-level science and math courses, some students have completed college-level science and math courses recently, and others may be returning to school after several years and have not completed college-level science and math courses recently. Perhaps due to the wide variety of backgrounds of students
enrolled in CHM 15, students enrolled in this course online displayed the most struggle with learning in an online environment. Because CHM 151 is designed for students majoring in a science discipline, students who need a high school science credit, and because this course is taken by students who have varying science and math backgrounds, I believe it is of paramount importance that students have an effective learning experience in this course. In addition to simple knowledge of chemistry content, I also believe that students need deeper, more authentic experiences in chemistry and to possess the skills to prepare them for higher level chemistry courses and scientific careers.

**Problem of Practice**

The COVID-19 pandemic and sudden shift to online instruction has served as a catalyst for me to design an effective inquiry method to teach online to diverse learners. As an instructor who has needed to adapt to the COVID-19 pandemic, I have struggled to design lessons that engage students in the online environment. At the beginning of the COVID-19 pandemic, inexperience in this form of teaching and my lack of time to adequately prepare lessons led to my students struggle in the online environment. I realized that I needed to design, use, and analyze new teaching methods to improve my teaching practice in the online classroom. The problem of practice addressed in this action research dissertation is that students are not effectively learning chemistry in an online classroom format. The intervention described in this dissertation will be the use and analysis of inquiry-based activities in an online chemistry class. In order to design and develop interactive inquiry activities in online chemistry courses, I also needed to obtain a deeper understanding of best practices to structure inquiry activities and to assess the inquiry activities.
Based on my observations of my instructional strategies and informal student feedback, I believe that there are three reasons why students struggle in online courses. The first reason is that there is often a large amount of new information for students to process at one time. In a seated classroom lecture, I could introduce new material in manageable amounts in a logical format and I could offer feedback and assistance to students as needed. In an online format, many students found large amounts of new material overwhelming and difficult to process at one time. In an online format, I lost the ability to review previous concepts on an as-needed basis. In an online format, students that need timely assistance did not have the ability to ask me for clarification as needed.

A second reason I believe that my students struggle in an online classroom environment is a lack of organization of content in the online classroom. In a seated classroom lecture, I could offer short review lectures on previous material to give students a review of previous important concepts. I could easily change my order of topics in a lecture or activity to better meet the learning needs of my students. In an online course environment, I lost that ability to review as needed. Rather than process new information in smaller units, students felt overwhelmed with large, sometimes unrelated, units of new information encountered in an online course. It is difficult to change the order of topics or offer individualized review as needed in an online course.

A third reason that students may struggle in an online environment is a loss of collaboration. In a seated class, group activities were typically completed in groups of 3-4 in collaboration with the instructor. In an online course, the student collaboration was not guaranteed. Students completed work independently and at different times during the week. In the seated, in-person format, students could ask each other for assistance and
clarify key concepts among themselves during group work. In an online classroom, students lost the collaboration skills and the personal connections made in small groups. Students lost the ability to ask one another for assistance and obtain timely feedback from me and from each other.

In designing effective online learning activities, development of engagement and the sense of presence in an online course is a main factor in student success (Stavredes & Herder, 2014). Stavredes and Herder summarize the importance of presence as “development of presence in the online environment is essential for learning to occur and the lack of it can cause learners to become dissatisfied and eventually drop out” (p. 83). Stavredes and Herder list the three main types of presence as teaching presence, cognitive presence, and social presence. Teaching presence is the teacher developing effective instructional practices and units, facilitating discussions and interactions, and offering effective feedback to students. Cognitive presence is how students construct meaning of the importance of the course materials and how students focus on higher-level outcomes. Cognitive presence is rooted in the constructivist model of learning; a deeper description of constructivism will be covered later in this chapter and as part of chapter 2, the literature review. Finally, social presence involves the interaction of students with each other, respectfully critiquing other ideas, and developing trust among each other. Social presence is also rooted in the social constructivist model of learning; a deeper description of social constructivism will be covered later in this chapter and as part of chapter 2, the literature review.

The problem of practice is that students are not effectively learning chemistry in an online format and I, as the instructor, struggle to teach chemistry effectively in an
online format. The main reason for the problem of practice may be due to the lack of three forms of presence in the current format of the online chemistry class. The development of an effective online inquiry activity, as part of an intervention to address the problem of practice, would be an effective method to develop the three types of presence for students and for me, as the instructor, in the online chemistry course. In the traditional format featuring online lectures, I had little chance to offer interaction or feedback to students aside from an occasional quiz or test. An effective inquiry activity would allow me a teaching presence to facilitate interactions between students and for me to offer timely, effective feedback to students. In a traditional lecture format, the focus was on lower-level learning without a deeper conceptual understanding of the course content. Assessment in the traditional lecture format and in previous online courses seemed to be recall or multiple-choice questions that did not facilitate deeper, critical thinking among students. An effective inquiry activity would be grounded deep in the constructivist model of teaching and learning. The effective inquiry activity would allow students to make connections to their everyday life and build on previous learning, either in home or school, experiences. The effective inquiry activity would offer many opportunities for students to reflect on their learning. Finally, my traditional lecture approach to online classes did not allow for social interaction among students. An effective inquiry activity would allow students to interact with each other and provide students a structured framework to interact with each other.

In designing an effective online inquiry activity, I needed to account for the recommendations of professional societies on appropriate course content. The National Research Council (NRC) (2012) and American Chemical Society (ACS) (2015)
recommends key content areas or core ideas for each scientific discipline. The NRC lists
the core ideas of physical science and chemistry to be matter and interactions, the role of
forces in the interaction of matter, energy, and waves. The course content of CHM 151
emphasizes the first of these three core ideas. In particular, the textbook I currently use
for CHM 151 emphasizes the particulate nature of matter, atomic theory, and kinetic-
molecular theory in explaining the properties and interactions of matter and the role that
energy has in chemical and physical processes (Tro, 2018). These core ideas are
emphasized several times throughout the CHM 151 course. An effective inquiry activity
allows for students to assess and relate to their prior learning in these key areas and
assists students in developing a deeper understanding of these course ideas. Development
of deeper understanding of course ideas would lead to success in the class and in future
classes.

As a teacher, as I developed and used inquiry-based activities in the online
classroom, I also needed to deeply examine my own understanding of inquiry-based
learning. I needed a method or tool to assess the activity and to assess how effectively I
used the inquiry activity in class. Not only does an effective inquiry activity need to be
developed, but I needed to ensure that I have an effective understanding of inquiry of my
own, I have the ability to develop other inquiry activities, and that I have a method to
assess how the activity was for improving student performance and attitude in the online
class.

There are several ways that this problem of practice aligns with action research. I
was studying my own practices of using inquiry activities in the online classroom. My
goal in completing this research is to improve my teaching practice and use of these
activities in the online classroom. My research can be used to develop more effective online learning activities and directly apply these findings to my teaching practice (Efron & Ravid, 2013). Action research is a cyclical and self-reflective process. I utilized the cyclical nature of action research and self-reflection to reflect upon and improve upon my implementation of inquiry in my online classroom. The self-reflection component of action research was performed at the beginning of the inquiry activities, in between different inquiry activities, and at the end of the inquiry activities.

**Theoretical Frameworks**

I recognized that the theories that framed my curriculum and instructional strategies in a seated, in-person course were not effective in an online CHM 151 course. In order to better address the problem of practice I observed in my online classroom, I realized that I need to change my curriculum and instructional theories and strategies. This section will provide an overview of the theoretical frameworks used to guide the design and implementation of changes in instructional strategy in an online CHM 151 course. Cognitive and social constructivism were used as the learning theory to design the instructional strategy. Connections were made to Culturally Responsive Teaching (CRT) to address the diversity of learners in the CHM 151 course. Then, the principles of effective online course design was used to transition the learning theory into the online classroom and provide an instructional design theory. Finally, the 5E model for inquiry-based teaching was then used to combine the principles of cognitive and social constructivism and effective online teaching in designing the intervention described in this dissertation.
In a traditional lecture classroom, I had always assumed that knowledge is simply transferred from the mind of the instructor to the mind of the student. This method had seemed effective for me as a student and I was comfortable with that method as an instructor. However, before the shift to online teaching and learning, I also realized that this method was not effective for some students. The transition to asynchronous online teaching and learning caused me to recognize that each student learns chemistry independently online and each student constructs the ideas of chemistry differently in their own mind. The idea that knowledge is not simply transferred but constructed is summarized as Piaget’s model of cognitive constructivism (Bonder, 1986; Cooper & Stowe, 2008). There are three key steps in Piaget’s (1970) functioning model of how learning occurs: observation and transformation onto previously learned mental models, adjustment of mental models or re-interpretation of observations, and organization of new mental models. The accuracy of the new model and structures is verified by constant questioning and interaction with a teacher (Bonder, 1986). Piaget (1950) also contributed ideas of learning stages. Piaget’s stages of learning are sensorimotor, preoperational, concrete, and formal. The sensorimotor and preoperational stages typically occur between birth and age 7 and pertain to object permanence and language development. In the concrete stage, students need explicit context, physical models, and hands-on activities in order to learn the main concepts. In contrast, the formal thinking stage is independent of context and physical models. Several chemistry teachers (Herron, 1975; McKinnon and Renner, 1971) provided data that approximately half of college freshmen are at the concrete operational stage of learning. Students at the concrete stage may not be able to activate deeper reasoning when solving chemical problems (Herron, 1985). In
reflecting on my transition to online teaching and learning, I was not considering the mental models that students had of chemical processes before completing activities. I was not aware of how students would change or adapt their models, and the possible confusion that incorrect mental models might cause as part of completing the activities. I was also assuming that many of my students were learning chemistry at the formal reasoning stage when instead they were learning chemistry at the concrete learning stage.

Because constructivist teaching methods relate to how students interpret events and observations with respect to their previous experiences, effective learning theory and instructional design was needed to account for the diversity of backgrounds of students in CHM 151. One method of improving the success and attitude of diverse students is Gay's (2002) culturally responsive pedagogy (CRP). Gay defined CRP as "using the cultural characteristics, experiences, and perspectives of ethnically diverse students as conduits for teaching them more effectively" (p. 106). CRP is rooted in the idea that when academic knowledge is positioned within the everyday experiences of students, the students' academic achievement and interest in the course improves. CRP also considers the methods of communication students with each other and has the instructor's design for communication with and between students to best meet their backgrounds. An effective teaching strategy for diverse learners, regardless whether in the online or traditional seated classroom, would need to account for the previous experiences of students, respect those previous experiences as important for learning, and allow students to make the connections between those everyday experiences and the course content. The teacher must be aware of the everyday life examples to which students would make
connections. Teachers must also develop ways for students to interact with each other meaningfully and respectfully.

Lee and Buxton (2010) summarized two important research findings for science teachers working with diverse students. First, direct lecture instruction is often a common, yet ineffective, tool for teaching diverse learners. I saw this concept reflected in both my online and seated classes with the struggles of diverse learners. Constructivist and hands on learning activities result in better outcomes for diverse learners. Secondly, diverse learners can find it challenging to adjust their previous mental models and structures; for diverse learners to learn effectively, the teacher must identify and make connections to students’ previous knowledge and experiences. One shortcoming in my previous experiences teaching diverse students, regardless if seated or online, was not asking for students' previous experiences and making a meaningful effort to make connections to students' everyday experiences. An effective instructional method would avoid direction instruction, feature hand-on learning, and allow students to make connections to previous learning.

In addition to changing the learning theories that shape my instruction, I also realized the need to adopt an instructional theory of effective online course design. As stated before, presence and communication are key components of online course design (Stavredes & Herder, 2104; IES, n. d.). Both social and teaching presence rely on clear feedback between the instructor and students and among groups of students. Consistent, timely feedback was missing in my original online course design. Consistent, timely feedback is also important because a key component of constructivism is the interaction and dialogue between instructors and students (Bonder, 1975). Another best practice is
the use of digital resources that promote self-regulated learning (IES, n. d.). As part of this best practice, IES recommends careful sequencing of the course content and scaffolding activities to increase student understanding of the material. This best practice also includes clear communication of instructions and feedback during the learning activities. In my original course design, the students felt overwhelmed with large amounts of material arranged in a non-logical format. In my original online course design, Piaget’s cycle was not occurring in a logical manner. Rather than have the cycle completed in several smaller manageable steps with appropriate scaffolding and feedback, the cycle was occurring once with a large amount of information. The design of the course also did not allow for me to clearly communicate my instructions to students as to how to complete the activities nor the appropriate sequence for the activities.

A final recommendation of the IES (n. d.) is to use appropriate simulation technologies in designing and delivering course content. The learning objectives associated with these simulation technologies should be clearly delineated first and then an appropriate simulation should be found and developed. To better align with their previous recommendations, an effective simulation should be at an appropriate level of complexity and course content, should offer instantaneous feedback to students, and should give the students a chance to reflect on their learning to assist in students developing higher-order thinking skills. The online learning simulation technologies would appeal to learners at the concrete learning stage. The chance to reflect, both individually and as a group, on the result of a simulation would lend itself to the reorganization and assimilation in cognitive and social constructivism. This recommendation would also relate to Stavredes & Herder’s (2014) concept of cognitive
presence, where student continually construct meaning and develop thinking and reasoning skills. An instructor who effectively structured the simulation technology for questions and feedback would be promoting teaching presence in the online course. The group reflection on the simulation technologies would also allow for both teaching presence and social presence between students in the online classroom.

In addition to an instructional method that uses best practices in online instructional design and utilizes constructivism teaching methods, a consistent method for structuring and scaffolding the inquiry activities needs to be used. A method of implementing inquiry-based science teaching is the 5E Model proposed by Bybee and the Biological Sciences Curriculum Specialists (Bybee, et al, 2006). The first step in this model is engagement, where the instructor captures a student’s interest in the problem. In addition to engaging the student’s interest in the problem, the engagement step allows for the instructor to gauge student misconceptions early in the learning process. This step aligns with CRP in that students are asked to make connections to their own experiences outside of school. Those experiences outside of school are not seen as unimportant or irrelevant, but as a starting point in the learning process. The second step of the 5E model is exploration. In this step, students explore the concepts of the first step and develop their understanding of the concepts through hands-on experimentation. Students begin to construct their own explanations of observations. The second step of exploration would be facilitated by the effective and appropriate simulation technologies. The exploration step would be designed using effective teaching presence, where the inquiry activities would be designed by the teacher to effectively communicate course content. The second step of exploration also helps students develop of cognitive presence in the online course.
The third and fourth steps of the 5E model are to explain and elaborate or extend. Bybee, et al. (2006) stated that the explain step should be facilitated by the instructor. The instructor highlights the important parts of the engage and explore steps and asks students for their own explanations of their observations. The instructor facilitates the process to make the relevant concepts more understandable for the students. The instructor also would clarify any misconceptions that students may have constructed. This step corresponds to the importance of teacher and student interaction in cognitive constructivism and in the relationship between cognitive and teaching presence for both students and the instructor. In the elaborate step, the goal is for the instructor to design activities that relate the concepts learned in the first three steps to similar and achievable, but also challenging and novel, activities or questions for the students to investigate. Once again, a connection can be made to CRP in that the instructor can choose examples that students may find in their everyday lives or students can be encouraged to find an everyday experience and explain that experience and observation using the models and explanations the students have developed in class. In the final step of evaluation, students and the instructor evaluate progress and concepts learned as part of the activity (Bybee, et al., 2006). Students would also relate the concepts learned as part of the activity to important scientific laws, theories, and models.

**Research Questions**

The purpose of this action research dissertation is to develop and analyze 5E inquiry activities in online chemistry classes. The research questions addressed in this dissertation will be:
1. How does incorporation of 5E inquiry activities affect student performance and attitudes in an online General Chemistry 1 (CHM 151) course?

2. How do I, the teacher / researcher, understand and use inquiry activities in online chemistry classes?

Student performance was assessed by analyzing the quality of student answers to activity questions, by using a post-test, and by using an embedded question on a student survey. Student attitudes were assessed by analyzing student responses on a discussion forum and student responses to Likert scale rating questions and short answer questions on a student survey. My own understanding of inquiry teaching was assessed by using a self-reflection journal and by using two outside rubrics designed to assess the quality of inquiry-based learning.

While the COVID-19 pandemic was the driving factor for the shift to online learning for Spring and Summer 2020 semesters, students may seek online science education for other reasons. Designing research questions and methods to assess and monitor those questions will lead to improved online chemistry teaching. Improved online teaching and learning will not only benefit students who were forced to enroll in online chemistry due to COVID-19, but other students who enroll in online chemistry for other reasons. By developing online inquiry activities, I believe that this intervention will improve students' understanding of the content areas of chemistry and their attitudes towards chemistry. Finally, I want to incorporate better and innovative practices in both online teaching and science teaching in my practice. Assessing my own abilities and understandings regarding online learning and inquiry-based teaching will improve my practice of online teaching and allow me to develop and use better learning activities.
In addition to content recommendations, the American Chemical Society (ACS) (2015) and the National Research Council (NRC) (2012) highlight several disciplinary practices and core ideas, such as developing models and graphical analysis of data, which are recommended for all types and levels of science classes. While these disciplinary practices are important for students’ success in a variety of science classes, these practices were not chosen to be part of the research question or inquiry activities. My purpose in using and analyzing the inquiry activities is to develop more effective online inquiry and teaching activities. Once those activities are developed and my skill and understanding of inquiry-based reaching is deepened, a future study would be to use and modify the effective online activities to better teach and assess disciplinary practices and core ideas. The challenge of developing activities, then adding on methods for teaching core ideas and disciplinary practices, and then assessing students’ understanding of both content and core ideas would add several layers of depth and complexity to this study. However, ideas for future study and how to better adapt these activities to teach disciplinary practices and core ideas will be further developed in chapter 5.

Another trend in chemical education is Process Oriented Guided Inquiry Learning (POGIL). Several studies using POGIL as the framework for inquiry activities will be examined in Chapter 2 in the literature review. However, there are several reasons why POGIL is not the framework for inquiry activities in this dissertation. A key component of POGIL is long-term group dynamics in a seated class and the activities described in this dissertation will be completed online. Chemistry educators struggle with adapting POGIL to the online classroom (POGIL, 2019). The challenges of adapting POGIL to an online environment would add an extra layer of depth and complexity to this dissertation.
The focus of this dissertation will be students completing inquiry activities individually with small group work at the end of the activity. However, future studies may investigate how to integrate POGIL group dynamics and principles with online inquiry and modeling activities. In addition, the group dynamics of POGIL may prove to be ideal for the learning of students from diverse backgrounds. The relationship of group dynamics to diversity of learners will be further described in Chapter 2 and ideas for future study will be discussed in chapter 5.

**Researcher Positionality**

This section will describe my positionality towards my students and positionality towards my research as part of this dissertation. As stated earlier in this dissertation, I have 15 years of experience teaching chemistry in the community college setting. I am also a graduate of a community college.

With respect to professional positionality, I was both a researcher and practitioner in this study. As a practitioner, I developed at least two 5E based modeling inquiry activity to use in my own online classroom. As a researcher, I analyzed my students’ outcomes and attitudes and my abilities and understanding of these activities. In terms of positionality, I would fall on Herr and Anderson’s (2015) scale of being an insider in collaboration with other insiders. I implemented and assessed the results in my own class. I always value informal student feedback; however, I would need to be cautious of how I interpreted informal student feedback about the design of the activities. To maintain objectivity and provide triangulation of data, a peer reviewer, with a Doctor of Education degree in community college leadership who uses inquiry-based activities in
her own classes, provided an outside perspective on online course design. My original plans included me disclosing to my students that they are part of dissertation research.

**Research Design**

This section will describe the context and setting, participants, methodological design, instruments, and methods of data collection and analysis used in this action research dissertation. This dissertation utilized action research-based qualitative methods. The research questions were addressed by the use of documentary analysis of student discussion forum posts, qualitative results with simple descriptive statistics of a conceptual test of student understanding, a student survey about their experiences, an instructor self-reflection journal, and rubrics to analyze the organization of the online inquiry activities.

The context and setting of the study was my community college, Colleton County Community College (pseudonym, abbreviated as CCCC) located in Colleton County (pseudonym), North Carolina. In both Colleton County and CCCC, approximately 80% of students are white, with the remaining 20% being roughly divided between Asian, Hispanic, and African American racial and ethnic backgrounds. Almost 20% of residents are at or below the poverty line.

This dissertation used an action research methodology to address the research question. There are three types of knowledge interests and goals of an action research study (Herr & Anderson, 2015). These three types of knowledge interests and goals are technical, practical, and emancipatory. While all three of these types of knowledge interests are important, this dissertation focuses on the practical interests and goals of action research. The practical interest of an action research study is to determine how
participants interpret events and how participants understand those events. In this study, I analyzed how both my students and I understand and interpret learning in 5E inquiry-based online learning activities.

This dissertation used qualitative methods to address the research questions. Qualitative methods are appropriate for this study for a variety of reasons. First, qualitative research is useful with small, limited sample sizes. The sample size in this study was limited to students enrolled in the online chemistry course at CCCC. Secondly, qualitative research is used to determine how individuals interpret experiences and construct meaning to those experiences (Merriam & Tisdell, 2015). I studied how I and my student interpreted the 5E inquiry-based modeling activities and how my students and I constructed meaning and understanding of chemistry concepts associated with those experiences. I recognize that my students and I might interpret the 5E inquiry-based modeling activities differently. One theoretical framework used in this study will be cognitive constructivism. Qualitative research is well suited to determine how knowledge is constructed differently in the minds of individuals (Merriam & Tisdell, 2015).

Qualitative studies allow for the practitioner and researcher to determine how learning takes place in the context of a classroom (Klehr, 2012). This action research dissertation will focus on determining how learning takes place in an online context. Qualitative studies focus on an inductive analysis of instruments and theory generation. I will analyze student discussion forums and student survey response for major themes and trends in how students viewed the inquiry-based activities. I will also be analyzing my own self-reflections for major themes and trends and use that to generate models and theories about how I perceive and implement inquiry-based online activities.
The 5E inquiry-based modeling activity will be introduced in the online CHM 151 course I will be teaching in a sixteen-week spring semester session. The inquiry activities will occur at approximately week six of the course. The 5E inquiry-based inquiry activities will be broken into several shorter activities that students will complete sequentially, preferably one per day. For the first research question, three data instruments will be used to evaluate student understanding and attitudes towards inquiry. The first instrument is structured discussion forum posts, the second is a conceptual test of understanding, and the third is a survey with Likert-style and short answer questions. For the second research question, three data collection instruments will be used. The first data collection instrument is a self-reflection journal for myself (the instructor) that I will complete before and after the inquiry activities. The second and third instruments are two literature-based rubrics to analyze the organization of the online inquiry activities and my role in the activities. Both I and the peer reviewer will complete these rubrics and compare results and discuss any areas of agreement or disagreement. I will also compare my journal entries with the observations of the peer reviewer. Finally, I will determine any areas of agreement and connection or areas of disagreement between my students’ understanding of inquiry and my own understanding of inquiry.

There are several ways to address quality and validity criteria in action research. Herr and Anderson (2015) list the goals of action research and methods to address the quality and validity of those goals. The goal of the generation of new knowledge is verified by dialogic and process validity. I will validate this goal by carefully examining my personal journals and determining the alignment between students’ results on the conceptual test, student understandings about inquiry, and my own understanding of
inquiry. I will also validate this goal by the alignment between my personal journal and the observations and evaluation of my online inquiry activity design. Outcome validity will be noted by student scores on the assessment test. The education of both the researcher and the participants is addressed by catalytic validity. I will address catalytic validity by examining how my reflections on inquiry-based teaching change during the unit, how student scores on assessments change, and the connection (if any) between them. Relevance to local conditions is addressed by democratic validity. I will ensure that the activities are related to the considerations of teaching online General Chemistry 1 in a community college setting. Process validity is addressed by using a sound methodological approach. The conceptual test is based on Yezierski & Birk’s (2006) Particulate Nature of Matter test. The questions in my reflection journal will be based on the questions by Rushton, Lotter, and Singer (2011) used to study teacher’s development of understanding of inquiry-based learning. The rubrics used to evaluate the online course are based on the Reformed Teaching Observation Protocol (RTOP) instrument (Sawada, et al., 2000) and Electronic Quality of Inquiry Protocol (EQUIP) instrument (Marshall, Horton, Smart, & Llewellyn, 2009).

Significance of Study

The problem of practice addressed in this action research dissertation will be designing online inquiry-activities to improve student learning and attitudes in online chemistry courses. This dissertation will address the use and analysis of using online inquiry-based activities and also address how I can improve my teaching of inquiry in an online environment. Because this action research dissertation is designed to address teaching and learning in an online environment, my students and I are the major
stakeholders in this study. My students will benefit from improved instructional practices and the improvement in teaching and learning chemistry. My teaching practice will benefit from the knowledge about inquiry generated as part of this dissertation.

As stated previously, action research is appropriate for this study because I chiefly studied my own practice as a science teacher (Herr & Anderson, 2015). Action research was also used because I addressed a problem specifically observed in my own classroom. I will be generating local knowledge used to solve a local problem and directly improving my own teaching (Efron & Ravid, 2013).

Action research is not intended to be generalizable or have external validity. While this action research dissertation will be devoted to the development and analysis of a 5E inquiry activity in an online General Chemistry 1 course, this dissertation could be of interest to other instructors of online chemistry courses. Students enrolled in online chemistry courses could benefit from this research. These activities could also be adapted to be used in seated, in-person classes. Other instructors of online and seated chemistry courses could also benefit from the improved teaching methods developed in this dissertation. As stated previously, in the future these activities could be expanded to teach core ideas and disciplinary practices in chemistry. These activities could also be expanded to facilitate other instructors who use the POGIL method of teaching inquiry.

Limitations of the Study

One possible limitation could be that demographics in online CHM 151 do not represent Colleton County Community College as a whole or the normal enrollment patterns in CHM 151. Due to the COVID-19 pandemic, students have been learning online for a year. Another limitation to this study may be that students are suffering from
burn-out and dissatisfaction with online learning and may have a negative view of online learning due to a year of forced online learning. However, students may also be frustrated with non-engaging lectures and activities in my courses and other instructors’ courses. Therefore, students may be more open to new methods of learning in an online class and have very favorable views of these activities.

**Organization of the Dissertation**

Chapter 2 of this dissertation will provide a literature review. In the literature review, the development of the theoretical framework of constructivist teaching in science will be traced. Connections will be made between CRP and constructivist teaching practices. The literature review will also survey key studies related to inquiry in the science classroom and teachers’ understanding and use of inquiry. Chapter 3 will further describe the methodology of this study and how the methodology relates to the theoretical framework and best practices in online course design. Chapter 4 will be the analysis of data. Chapter 5 will contain recommendations and suggestions for future study to build on the key findings of this dissertation.

**Glossary of Terms**

5E: An instructional model based on “five phases of learning: engage, explore, explain, elaborate, and evaluate” (Bybee, 2015, p. 4).
CHAPTER 2
LITERATURE REVIEW

My current community college’s mission is to provide accessible, high-quality education that improves lives and promotes growth in our community. The problem of practice addressed in this action research dissertation is that students struggle to learn chemistry in an online class and I struggle to teach chemistry in an online classroom. The problem of practice also involves my growth and development of my understanding and competence at designing and assessing online chemistry activities. By finding innovative ways to develop inquiry activates, all students enrolled in the online chemistry course will benefit. In addition, these inquiry activities could be used in other chemistry and science courses in future semesters. My improvement in using inquiry will also aid in developing high-quality inquiry activities in future semesters. Increasing student achievement in chemistry and science courses can lead to positive economic and intellectual growth for students, their families, and the local community.

This chapter will be divided into theoretical frameworks, historical perspectives, and related research. The theoretical frameworks will examine methods of teaching chemistry and contributions from Piaget and Vygotsky. The second section of the literature review will focus on historical development and examples of inquiry-based learning. The third and final section of the literature review will examine several studies and examples of inquiry-based learning in college science classes. The general description of each study, results, limitations, and implications for the 5E inquiry
activities presented in this dissertation will be given for each. In addition, connections to culturally relevant pedagogy and best practices for diverse learners will be addressed in each section.

**Research Questions**

1. How does incorporation of 5E inquiry activities affect student performance and attitudes in online General Chemistry 1 and 2 (CHM 151 and 152) courses?

2. How do I, the teacher/researcher, understand and use inquiry activities in online chemistry classes?

**Purpose of Literature Review**

Efron and Ravid (2013) stated that an action researcher wants to link educational theory to practice and to relate broad studies to specific cases in the researcher’s classroom and school. One method of connecting the classroom to broad theory of teaching and learning is a literature review. The literature review is “a summary and synthesis of research put forward by others that is pertinent to your [the researcher’s] own inquiry” (p. 17). In order to link educational theory to practice and relate broad studies to my specific local conditions and problems, I have performed literature searches related to effective teaching and learning in chemistry and science classrooms and inquiry in science classrooms.

Books related to the teaching of chemistry were used to begin the literature search. These were mined for journal articles, references, and primary sources. The ERIC (EBSCO) and ERIC (ProQuest) databases and peer-reviewed journals related to science teaching were also used in the literature search. Keywords of “General Chemistry,” and “5E Practices” were first in all databases. Due to low numbers of
relevant studies in several databases and journals, searches were expanded to include “inquiry” in place of “5E Practices.” Journal articles were analyzed to determine good cases where inquiry activities were used in college science classrooms.

**Theoretical Frameworks**

This section will present the theoretical foundations of constructivist and inquiry-based learning. First, the theoretical framework behind traditional approaches to chemistry teaching will be presented. This will then be contrasted with constructivist theory towards teaching. The contributions of Piaget and Vygotsky to constructivist learning will also be examined.

**Traditional Approaches to Teaching Chemistry**

Most traditional approaches to the teaching of chemistry are instructor centered, focus on behavioral and cognitivist approaches, and are scholar-academic in nature. Cooper and Stowe (2018) cited several examples, some from as early as 1893, where effective chemistry teaching was only defined in terms of the instructor’s enthusiasm for the subject matter and personality for teaching. The instructor was at the center of students maintaining interest in the subject matter; the instructor needed to devise clever ways to deliver the information to the students in entertaining ways during lectures. Copper and Stowe also noted that many early chemistry textbooks focused on giving students knowledge to prepare them for careers in industry without concerns for deeper understanding of chemical concepts. Cracolice (2005) stated that the traditional view of chemistry teaching is that being an expert chemist automatically makes an individual qualified to be an expert chemistry teacher simply because the expert chemist has experience in being a student! These relationships are reflective of Schiro’s (2013)
One logical problem with this traditional approach is that the prior knowledge of the instructor and the prior knowledge that the instructor assumes that the students have may not align with the actual prior knowledge of the student (Bonder, 1986; Cracolice, 2005). The traditional approach does not include the previous personal, lived experiences of the students. McGuire (2015) gave an example of confusion that arose during a lecture on gas laws and properties. McGuire had designed and delivered what she thought was an effective lecture on the properties of gases (oxygen, nitrogen, and hydrogen) in the air and compared those properties to different states of matter; however, she had an intelligent student who could not make sense of her lecture. This student had pictured liquid gasoline as an example of a “gas” during her lecture! The student had made a connection to a previous personal experience, but the experience did not correctly connect to the lesson that McGuire had prepared. If the student and instructor do not have an alignment of terms and concepts, then little meaningful learning can occur. If McGuire would have made more direct connections with the student’s everyday experiences or allowed for opportunities to assess the student’s prior knowledge, this misunderstanding would not have happened.

**Theoretical Framework for Constructivism, Piaget, and Vygotsky**

One method of countering misconceptions that can occur early in learning is by shifting to a constructivist approach to learning. Bonder (1986) summarized the constructivist approach as “knowledge is constructed in the mind of the learner” (p. 873). Ertmer and Newby extended this definition as that “learners build personal interpretations
of world based on individual experiences and interactions” (p. 55). In the McGuire (2015) example, the student had constructed knowledge (of gases in the air) in their mind based on models of and previous experiences with gasoline!

Piaget is credited with making a shift from traditional behavioral and cognitivist approaches to learning to constructivist basis of learning (Bonder, 1986; Herron, 1975). Two key contributions of Piaget (1970) are a reorganization of how learning occurs and the classification of different types of learners. There are three key steps in Piaget’s functioning model of how learning occurs. In the first step, observations from the environment are transformed or assimilated onto previously learned mental models and structures. If there is conflict between the models and observations, disequilibrium takes place. In the second step of accommodation, equilibrium is restored when either the previous mental model is changed or the current observation is reinterpreted. In the final step of organization, the new structures, models, or observations are aligned with previous structures, models, and observations. In the McGuire (2005) example, the student was trying to fit new information and observations about gases in the air into previously learned models of liquid gasoline. When the student tried to make sense of the new material, the student incorrectly fit the new material onto incorrect mental models. The organization the student had made about models of gases in the air was completely incorrect.

Piaget (1950) also contributed ideas of learning stages. Piaget’s stages of learning are sensorimotor, preoperational, concrete, and formal. The sensorimotor and preoperational stages typically occur between birth and age 7 and pertain to object permanence and language development. While Piaget originally set the age distinction
between concrete and formal at around age 11; awareness of these stages is important for college teachers. In the concrete stage, students need physical models, representations, and hands-on activities in order to think about the objects, phenomenon, or concept. Students at this stage also operate within highly specific contexts and highly dependent word clues. In contrast, the formal thinking stage is independent of context and physical models. In comparing these two types of stages for chemistry students, Cracolice (2005) stated that a concrete learner, in learning how a solution forms on a molecular level, would need to have the process drawn out step by step or perform hands-on experiments to see how the solution forms. On the other hand, the formal learner can read a textbook description of how a solution forms on a molecular level and correctly form a mental model of the process. Several chemistry teachers (Herron, 1975; McKinnon and Renner, 1971) provided data that approximately half of college freshman are at the concrete operational stage of learning. A consequence of these stages is that students at the concrete stage may not be able to make deeper reasoning when solving chemical problems (Herron, 1975) or be able to understand and apply course concepts after completing the chemistry course (Lawson and Renner, 1975).

A criticism applied to Piaget is that he is a “cognitive constructivist” (Cooper & Stowe, 2018, p. 6057) in that knowledge is constructed only in the mind of the individual with interactions between the individual and the environment. This is also termed endogenous constructivism by Applefield and Huber (2000). There is no room for group learning or group contributions in this model. For learning to occur, the interactions between the learner and peers and the learner and the instructor must also be considered in the learning activity design (Bunce, 2001). Several chemistry instructors (Bunce,
2001; Cooper and Stowe, 2018; Cracolice, 2005) appealed to Vygotsky’s model of social constructivism and zone of proximal development to account for interactions in learning.

Vygotsky’s emphasis was the social conditions and interactions in which learning occurs (Cooper and Stowe, 2018). Vygotsky (1978) described the zone of proximal development as the difference between a student’s actual learning level and the level determined by instructors or more experienced classmates. The purpose of the instructor or classmates is to give limited guidance and hints to help the student increase problem solving skills and deeper understanding. For example, Cracolice (2005) described an example where a student may be struggling with chemical calculations. The classmates or instructor would check to see if the student understood the individual concepts related to the calculations. If so, more reinforcement and clarification would be provided; if not, then the different concepts would be linked together. This type of constructivism is also known as dialectical constructivism, where "the origin of knowledge construction as being the social intersection of people, interactions that involve sharing, comparing and debating among learners and mentors" (Applefield & Huber, 2000, p. 38).

**Historical Approaches**

This section examines how inquiry teaching has been used in several cases. An overview of inquiry-based models for teaching and their relationships to Piaget’s functioning model is presented. Next, a seminal study regarding inquiry in the college general chemistry classroom is analyzed.
A General Model of Inquiry Based Activities

In the 1950s, Robert Karplus became interested in the learning patterns and styles of children. He began to make connections between the learning theories developed by Piaget and how teaching and learning in science classes occurs (Bybee et al., 2006). In collaboration with J. Myron Adkin, they developed a model of guided discovery (Adkin & Karplus, 1962). In their model of guided discovery and inquiry, learning takes place in three stages: exploration, invention, and discovery. These three stages are described below (Abraham, 2005; Adkin and Karplus, 1962; Bybee et al., 2006)

1. **Exploration.** Students have hands on learning and initial experience with the phenomenon or concept being studied. This would be similar to the assimilation step in Piaget’s functioning model where new information is taken in and compared to existing mental structures.

2. **Invention.** Students are presented with terms related to the phenomenon being studied. This would be similar to the accommodation step in Piaget’s functioning model. Previous mental models and structures are reorganized to accommodate new material.

3. **Discovery.** Students use the newly invented concepts to analyze similar, but slightly different, situations and cases. This would be similar to the organization step in Piaget’s functioning model. The organization and structures of the new concept are compared to new situations.

One main criticism of this model (Bybee et al., 2006) is that there is no engagement of the student. There are no cues or hints as to why the phenomenon is important nor how it relates to everyday life. There is not a connection to the everyday experiences of the
student. This model may have the same limitations to McGuire’s (2015) gas and gasoline misconception if the instructor does not gauge the previous experiences of the student or make explicit connections to everyday experiences. In the Adkin & Karplus model there is also no evaluation at the very end for the instructor to verify if the invented models are correct.

5E Inquiry Model

Bybee et al. (2006), through their work with the Biological Sciences Curriculum Specialists, are widely credited with developing the 5E model for inquiry-based activities in science courses. Holly Travis is a biology instructor at Indiana University of Pennsylvania and has used this model to teach the properties of water and the chemical structure of a water molecule in several biology courses. The five steps of the 5E model will be presented, also in alignment with Travis’s (2013) examples of how these steps for inquiry are used in class. The 5E model features five steps for an inquiry-based activity: engagement, exploration, explanation, elaboration (or extend), and evaluation. The first step is engagement. Bybee et al. (2006) suggested that engagement “involves making connections to past experiences and exposing students’ misconceptions” (p. 8). Bybee et al. listed several ways that an instructor can engage students. Posing a question, performing a demonstration, or a short video are all ways to engage students in the inquiry activity. In college-level classes, Travis (2013) suggested using a question to review the previous day’s lecture or a short paper on what students think they already know about a problem. In the water unit, Travis has students list ten items each student thinks they know about water. This step in not present in the Adkins-Karplus guided discovery model. This step helps bring to mind prior knowledge, promote expectancy,
and bring prior experiences to working memory (Gangè & Medskar, 1996). This first step helps students see how and why the lesson may be important in their everyday lives. This first step is also important for the teacher to gauge the student's prior learning, experiences, and any misconceptions. This first step also aligns well with the focus of CRP to make explicit connections to the student's everyday lived experiences. However, one consideration is that the instructor must ensure that the examples used must be relevant to the students’ everyday experiences, otherwise the students will not understand the relevance of the lesson and may feel excluded by the teacher (Lee & Buxton, 2010). For example, in the water unit, certain types of students may not have experiences at a swimming pool or lake. If an instructor asked students to consider their experiences at a swimming pool or lake certain groups of students would not make the necessary connections to everyday life and may be excluded from learning.

The second part of the 5E model is exploration. In the exploration phase, students should be exposed to mental and/or physical activities to explore the topic (Bybee et al., 2006). The purpose of this phase is to establish experiences for the students and the teacher acts as a facilitator and coach. The teacher begins to guide and coach the students through developing mental models of the phenomenon and possible explanations. In the water lesson, Travis (2013) gives a humorous example of students describing water as wet; this simple statement is used to have the students explore the properties of water and why water is a liquid at room temperature. Travis uses a question-and-answer format to coach and guide students through exploration and model and explanation development. As the name implies, this step is similar to the exploration phase in the Adkins-Karplus
guided discovery model. In Piaget’s classifications of learners, concrete learning experiences are being used to involve and stimulate concrete learners.

The third part of the 5E model is explanation. The teacher probes students for their possible explanations and models after their exploration activity (Bybee et al., 2006). The teacher then introduces the formal, technical terminology to explain the students’ observations. This explanation phase may be done in small groups or as a class lecture. Travis (2013) noted an example of a student mentioning how a belly flop hurts while swimming. Travis uses this to introduce the concepts of surface tension, adhesion, and cohesion as they relate to the properties of water. This is the invention of concepts steps in the Adkins-Karplus guided discovery model. In Paiget’s classifications of development of learners, this step helps transition from concrete to formal thinking. The small group nature of this step also uses Vygotsky’s social constructivism and zone of proximal development to help students work together to develop mental models and structures.

The fourth part of the 5E model is elaboration (or extend). Bybee et al. (2006) defined elaboration as it “facilitates the transfer of concepts to closely related but new situations” (p. 10). Bybee et al. suggested that this step be performed in a small group setting, so students can receive peer feedback. The result of this part in the 5E model is transfer and generalization of concepts. Travis (2013) used pair-share activities or discussions at this part of the activity. After having students learn about adhesion, cohesion, and surface tension of water, students are posed a question to explain how water moves in a plant. In discussions about different types of solutions, osmosis, and diffusion with the properties of water, students are posed a question involving
dehydration and asked to predict how water will flow across cell membranes in these cases. This is similar to the Adkins-Karplus guided discovery model of application to new, slightly different scenarios. This step also promotes students to transition from concrete thinking to formal, abstract thinking. In another connection to CRP, students can be encouraged to find examples of the chemistry concept in their everyday life, interpret and explain that everyday life example, and report their example back to their classmates.

The final part of the 5E model is evaluation. While feedback from the instructor and peers is embedded throughout the 5E model process, this part is intended as a summative evaluation of the students’ understanding of the material (Bybee et al., 2006). The teacher should give sufficient feedback, not just about whether students have gotten the right answer, but also feedback as to the quality of students’ models, thought processes, and explanations. This is also the section where learning objectives can be assessed. Travis (2013) suggested using one minute or summary papers at the end of the activity. Travis suggests that the teacher review these papers to give the students’ feedback and to build the opening question or activity for the next 5E inquiry activity. This evaluation step is missing from the Adkins-Karplus guided discovery model; this step allows for a final assessment by the instructor. This final step also ensures that correct mental models and structures have been built so students can progress to higher learning. The following table summarizes the relationship between Piaget’s functioning model, Adkins-Karplus learning cycle, and 5E learning cycle (Abraham, 2005; Bybee et al., 2006). **Table 2.1** lists a comparison of types of inquiry based learning cycles.
Guided Inquiry Study at Franklin and Marshall College

One of the pivotal studies regarding inquiry teaching in the college chemistry classroom is by Farrell, Moog, and Spencer (1999). They drew heavily from Herron’s (1975) and Bonder’s (1986) previous works to develop inquiry-based activities used throughout the course. Herron (1975) made the connection between Piaget’s stages of development and success in college chemistry classes. Bonder (1986) made the connection between traditional approaches to teaching and misconceptions and how constructivist models can reduce misconceptions. Farrell, Moog, and Spencer (1999) reported their implementation of inquiry learning in a first-year general chemistry course at Franklin and Marshall College, a private university in Lancaster, PA. In statistics cited by Farrell, Moog, and Spencer, the general chemistry course is taken by approximately 240 students per year, with about 25 students per section. This is the only introductory first year chemistry class at Franklin and Marshall and this course enrolls a variety of science and non-science majors. This study is a mixed methods study, with results focusing on both student grades and student attitudes towards inquiry teaching and the chemistry course.

The instructors use students in groups of 4-5 with assigned roles depending on daily attendance (Farrell, Moog, and Spencer 1999). The recorder physically records on a group answer sheet the group response to questions and solutions to problems. The technician is the only group member to use technology, such as calculators or lab equipment for demonstrations. The reflector serves to manage group dynamics and roles and to help other students reflect and think about their thinking. The presenter will present and explain answers to the instructor or to the class. The manager makes sure all group members are following assigned roles and staying on task. While students may
have some distinct roles, all are expected to contribute models, ideas, and explanations to the groupwork. Students switch roles each class period; students are given the chance to take on all roles and improve on their performance in each role. This setup also allows students develop problem solving skills. The instructor only facilitates group inquiry activities. The instructor does not give a formal lecture and does not answer any question that the students could answer on their own. However, the instructor may give guidance or hints to the student about how to arrive at the answer to the student's question.

Students do have a traditional textbook for readings to reinforce inquiry activities after the group inquiry approach is over. Like their counterparts in a traditional class, students are given traditional exams and a final exam.

In Farrell, Moog, and Spencer’s study (1999), the instructors designed the inquiry activities with three basic parts. The first part is for students to examine a model, data, or information. Second in their guided inquiry activities are critical thinking questions. These questions are designed to guide and lead students to analyze data and to make inferences and conclusions. Finally, students work through application questions to give students more practice in solving problems like the critical thinking questions. While this study was completed without formal use of the 5E inquiry model, their examination of a model would parallel the engage section of the 5E model. Their use of critical thinking questions would be similar to the use of exploration and explanation in the 5E model. The application questions would be similar to the elaborate and evaluate sections of the 5E model.

Farrell, Moog, and Spencer (1999) reported that their $D$, $F$, and $W$ final grade rate went from 21% before inquiry activities were established to 10% after the incorporation
of inquiry activities. In terms of qualitative results, they report that students have positive attitudes towards the course and teaching method. They also report that students in the guided inquiry sections specifically requested to take their next chemistry class using the guided inquiry method. As a result of this study, a resource of inquiry activities was developed by Moog and Spencer (2002).

Another feature noted by Farrell, Moog, and Spencer (1999) was the effect of group dynamics on their study. The researchers also took student performance and gender into account when assigning students to groups; the researchers made an effort to have the groups be heterogeneous in composition. Group composition varied early in the semester, but groups stabilized towards the end of the semester. In a survey of a selected small group of 96 students, 48 of the students report positive effects of groupwork and an additional 21 students found this method preferable to traditional lecture. The researchers’ use of group work reinforces Vygotsky’s zone of proximal development and social constructivism in the effective use of inquiry in a chemistry course.

One limitation of the Farrell, Moog, and Spencer (1999) study is that the methods used in their study were not based on the 5E method, their methods used the Adkins-Karplus guided discovery approach. There was not an official engagement step and students were not encouraged to make connections to everyday experiences. However, their results do show that inquiry activities, however formally structured, can increase student performance and attitudes. A second limitation is that Franklin and Marshall college is a selective private school; this dissertation will focus on an open door, public community college. The differing natures of institution, and student demographics, may cause inquiry activities to have different effects. The book developed by Moog and
Spencer using inquiry activities features mainly mental exercises and problems. However, very few demonstrations, lab activities, and connections to everyday life are included in their book.

**Related Research**

This section traces the development of inquiry-based teaching in college level science courses. First, a follow-up study (Lewis & Lewis, 2005) to the influential work of Farrell, Moog, and Spencer is examined. Next, a study where inquiry teaching methods are used in an introductory course for non-science majors (Conway, 2014) is presented. Other studies (Sen & Oskay, 2017; Travis, 2013; Walker, McGill, Buikema Jr., & Stevens, 2008) related to the 5E inquiry activity directly applied to college courses are included. Several assessment studies (Briggs, Long, and Owens, 2011; Cianciolo, Flory, and Atwell, 2006) of inquiry teaching methods are reviewed. Finally, applications to English Language Learners (Adams, Jessup, Criswell, Weaver-High & Rushton, 2015; Rosenbery, Wiseman & Conant, 1992) will conclude this section.

Lewis and Lewis (2005) reported the implementation of peer-led inquiry learning at the University of South Florida. While this study is more than six years old at the time of the writing of this dissertation, it serves as a key evaluation and follow-up of the Moog, Farrell, and Spencer (1999) study. This study was completed using first semester general chemistry; the authors do not specify if this course is taken by a variety or majors or by science majors alone. The authors primarily looked at student grades and secondarily looked at student attitudes towards inquiry learning. The researchers report that 151 students were enrolled in the control group and that 70 students were involved in the experimental group. In the control group, students were taught by traditional lecture
methods. In the experimental group, undergraduate “peer leaders” were used in place of instructors to facilitate student groups during guided inquiry learning activities. The students in the guided inquiry sections consistently performed better on unit and final exams than those in traditional lecture sections. Approximately three fourths of the students had positive attitudes towards the inquiry activities, stated that they would want to continue using inquiry activities in a subsequent course, and found group work aspect of the inquiry activities was beneficial. This study shows that the inquiry activities developed by Moog and Spencer can work in other settings.

Not only has inquiry been used to teach general chemistry, Conway (2014) reports of using inquiry methods to teach several courses of a one-semester general, organic, and biochemistry survey course. In this study, several courses were studied over several years. In each course, the average number of students per course was 30 – 40. This study involved using quantitative methods to study student grades and qualitative measurements to assess student attitudes. The experimental group consisted of courses that used inquiry methods, the control group consisted of courses from previous semesters. For courses that utilized inquiry methods, the researcher found that over 40% of students achieved an A as their final grade in the course. In comparison, in semesters that did not use guided inquiry, under 20% of students achieved an A as their final grade. The researcher also noticed a decrease in the number of C grades in the experimental group. The researcher also reports many positive comments from students about the guided inquiry activities. The students noted the positive effects of completing inquiry activities in groups and feeling like they have achieved a deeper understanding of what they have learned. The researcher sums up observations and results as “nonmajors often
are afraid of science courses, have less motivation, and do not find the material interesting… they perform better using student centered techniques than through a traditional lecture” (pp. 482–483). This study shows that inquiry can be used to increase the academic achievement and motivation of all types of students, not just science majors. The course used as part of this dissertation, while being designed for science majors, contains a large number of non-science majors. In particular, CHM 151 enrolls a large number of dual-enrolled high school students with a variety of interests and majors.

Travis’s (2013) biology classes were used to give examples of the 5E inquiry activities earlier in this literature review. Travis listed benefits that have been observed in classes using the 5E inquiry activities. Because of the high degree of instructor and teacher interaction, student anxiety and nervousness about learning science decreases and student attitudes about the course and material improve. Students are more able to see the relevance of the material and directly engage in the material. The emphasis on frequent interaction and feedback, improved attitudes, and engagement with the material has caused the withdrawal rate in these classes to decrease. Travis has also observed students with more motivation to complete advanced science classes and students being able to scientifically converse with medical professionals about material learned in class. Travis summarizes her main goals are to prepare students to be literate and conversant in science and to be able to think and reason through scientific issues.

Walker, McGill, Buikema Jr., and Stevens (2008) reported where a serial dilutions lab, in a microbiology course, was re-written to match the 5E inquiry format. The researchers acknowledge that serial dilution is a key laboratory technique not only in microbiology, but also in chemistry and other higher-level science courses. The research questions
posed by these researchers focuses on the difference between academic achievement and attitude in students taught by a 5E inquiry format (experimental groups) and students taught by traditional instructional methods (control group). The researchers did not report a sample size. After each group completed three lab periods of activities related to serial dilutions, to assess student learning in both the traditional and 5E inquiry methods sections, students were given a quiz with questions involving dilution calculations, concentrations, and experimental relationships. Students in both groups were also given attitudinal surveys. Videos of student groups performing these lab activities and small groups interviews were also used to determine student attitudes.

In an evaluation of the results, the quiz scores for the top and bottom quartiles in experimental and control groups did vary significantly (Walker et al., 2008). However, the middle quartiles in the experimental group were significantly larger than the control group. For the control group, the median score was 11.5 out of 14.0; for the experimental group, the median score was 13.0 out of 14.0 The researchers summarize these results as “it can be concluded that the inquiry-based learning strategy employed in this study increased the academic achievement of the ‘average’ student in the class” (p. 59). The authors report that there was not a significant difference in attitude in the experimental and control groups; the authors rationalize this as both groups appreciated the repetition of activities. Interestingly, student attitudes in the experimental group were negative at the start of the lab, possibly due to having to learn the material without direct instruction from the instructor. However, the students in the experimental group spoke highly of the hands-on activities used to introduce, or engage, the lesson. One limitation is that the course level in this study was sophomore, and the students in this study should have
completed at least one science course before completing the microbiology course. Therefore, the students in this study may have had a stronger science background and have been more motivated to complete the course. This dissertation will focus on a freshman level course with no prerequisites.

In a study that directly relates the 5E inquiry model to chemistry courses, Sen and Oskay (2017) conducted a study at Hacettepe University using 5E inquiry to teach the chemical equilibrium concept. There was a total of 34 participants in both control and experimental groups. The same instructor taught two courses; one course was taught in a traditional manner (control group) and the other was taught with a series of 5E activities (experimental group). In the experimental group, students performed a series of experiments related to equilibrium and the instructor took the role of a coach and facilitator. Student performance on an assessment test was used to determine effectiveness of the 5E inquiry activities and students’ attitudes were surveyed. The experimental group generated questions they wanted to answer about the equilibrium concept at the engagement phase of the activity. In the exploration phase, students performed a variety of lab activities related to equilibrium and their engagement questions. In the explanation portion, students, working in small groups, developed their own models and explanations for their observations. The students were coached and guided by the instructor during the exploration and explanation phases. In the elaboration phase, the students were challenged to apply their models and explanations to new systems. While evaluation was embedded throughout the activity, the summative assessments were a concept test on equilibrium and an attitude inventory. The researchers reported a higher score for achievement on the concept test for the
There are also several studies that examine the effectiveness of inquiry teaching. Briggs, Long, and Owens (2011) completed a qualitative study where an outside observer monitored the interactions between instructors and students during an inquiry-based teaching activity. The interactions between two students and an instructor were analyzed to determine how the student constructed knowledge and how the instructor interpreted and asked follow-up questions based on these models. Their main summary points were that close observation of student mental processes gives much greater insight than traditional exams, that instructors need to be flexible in how they ask questions of students and set up activities, and that instructors should carefully listen to their students for details in mental models and organizations.

A similar study by Cianciolo, Flory, and Atwell (2006) examined how often inquiry-based behaviors were used during classes. These researchers observed several classes that used both traditional lecture and inquiry methods. The researchers had a checklist of behaviors, such as investigations, modeling, and comparisons of predictions versus experiments, that they believed were associated with inquiry teaching. The researchers noted how often these behaviors occurred during lecture and inquiry sessions. They looked at behaviors of both students and instructors. While the obvious result was that inquiry-based teaching would have more inquiry associated behaviors, the researchers also noted that instructors engaged in inquiry-based behaviors more in lecture
after inquiry-based activities were used. In interacting with the instructor and other students during a traditional lecture, students use of inquiry associated behaviors also increased. Using inquiry in teaching caused an increase in inquiry-based behaviors in students and instructors, regardless if inquiry or traditional lecture approaches were being used.

In a link to social justice concerns, some students completing college general chemistry may be English Language Learners (ELL). They may have problems with translating a chemical statement or problem or they may be unfamiliar with how to phrase a question to the instructor. Adams, Jessup, Criswell, Weaver-High, and Rushton (2015) completed a study that involved ELL in a high school chemistry course. This course used inquiry-based activities in small groups where students were grouped based on language skills and content mastery. The researchers noted that students spoke in their native language more during high demand and complex tasks. The researchers suggest that if only English language is used, then students may have a difficult time expressing when and how they are having difficulties with the material. When students use their native language, there is less cognitive load and students are able to process more new information easily. The researchers also reported some improvement in mastery of course content; the results were lower than expected, possibly due to language confusion between how test questions were phrased and how students were answering those questions in English.

Rosenbery, Wiseman, and Conant (1992) conducted a study of how ELL middle and high school students used inquiry to improve their understanding of science terminology and their language acquisition skills. The study was conducted for a year and
students engaged in a variety of inquiry-based labs. These labs also featured connections to students' everyday experiences, for example studying the biology and ecology of local water sources. Students improved their understanding of scientific inquiry and scientific process. Other observations of this study were that language acquisition improved when students had a context, such as scientific process and inquiry, to learn the language. Students also felt confident in these activities because they could express their understanding of concepts in several communication formats.

In a study that related a biological science teacher's classroom practice of CRP to the teacher's and student's attitudes, Boutte, Kelly-Jackson, and Johnson (2010) list several key findings. In one classroom activity described in this study, the teacher first formally presented cell structure and function and then encouraged students to develop and find, in magazines, books, and newspapers, their own examples and analogies for cell structure and function. This activity allowed for more student engagement and allowed for the teacher to gauge the students' interests, for students to know their prior knowledge was validated, and for the teacher to understand the experiences that students brought to the classroom. Other examples in this study included teacher related DNA extraction and blood testing to students' favorite television shows and skin and hair chemistry to ethnic hair care. The teacher reported an increase in both student performance and attitudes towards science. The teacher also reported that she developed a deeper understanding of students, that the teacher found that she researched more examples for her to use with her students, and that she found that she researched and presented more about the work of racially and ethnically diverse scientists. One other finding of this study is that both the teacher and researchers recognized that long term improvements cannot be accomplished
in a single lesson. CRP science lessons must be used in the long term over the entire semester to result in long term improvements on outcomes and attitudes.

In an analysis of fifty two studies related to CRP in science classrooms, Brown (2017) noticed and reported on major connections between CRP and inquiry practices. One key finding is that using culturally relevant and everyday analogies and examples assists students in constructing explanations and models and in communicating results. Another key finding was that students showed more interest and understanding in data and interpretations when real-life social and political examples, such as air pollution analysis, were used to introduce the content in the classroom. Finally, culturally responsive engineering problems and examples can be used to successfully engage in mathematical reasoning and problem-solving.

Summary

Farrell, Moog, and Spencer laid the foundations for using inquiry techniques in the college chemistry classroom. Their textbook of inquiry activities, while mainly focused on thought experiments and paper and pencil written problems provide the basis for inquiry-based learning in chemistry. One issue regarding inquiry-based activities raised by Walker, et al. and Sen and Oskay is the initial resistance by students. Steps will be taken in this dissertation to reduce early resistance to inquiry-based activities. However, Cianciolo, Flory, and Atwell showed that once students and teachers start to use inquiry activities, the skills and actions associated with inquiry transfer to and are used in other classes and courses.

The Farrell, Moog, and Spencer, Lewis and Lewis, and Conway studies shows that inquiry can lead to reduced failure and withdrawal rates; one aim of this dissertation
is to reduce these rates for students. Walker et al., show that inquiry can engage and increase the academic performance of so-called average students. Boutte, Kelly-Jackson, and Johnson and Brown show that CRP can be successfully integrated into science curriculum to improve outcomes and attitudes of both teachers and students. Finally, as shown by Adams et al., another aim of this dissertation is to support English Language Learners in chemistry through inquiry activities, thus addressing a social justice concern related to English Language Learners.

One limitation to most studies about inquiry is that the studies only focus on the understanding of inquiry from the students' perspective. These studies feature a main focus on student grades and not on student attitudes and understandings about inquiry. These studies do not gauge or explain how the instructors using inquiry viewed the inquiry activity outside of student scores. Finally, these studies do not assess the structure of the activities or how the activities were implemented in class outside of student grades. A key component of this dissertation will be a self-study by the teacher / researcher on how he understands and uses inquiry in the classroom.

The subsequent Chapter 3 of this dissertation will describe the experimental design of this study. Chapter 3 will describe how both cognitive and social constructivism were used to select and design the activities in this study. Chapter 3 will also describe how the 5E model was implemented in two inquiry activities in online chemistry class. Chapter 3 address how performance and attitudes of students were measured at the end of the inquiry activities. Finally, Chapter 3 will describe how the teacher/researcher assessed his own understanding of inquiry and how effectively he had used inquiry in his classroom.
Table 2.1 Comparison of Inquiry Based Learning Cycles

<table>
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<th>Comparison of Piaget, Adkins-Karplus, and 5E Models</th>
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CHAPTER 3

METHODOLOGY

The problem of practice addressed in this action research dissertation is that students are not effectively learning in an online chemistry course and that I struggle to effectively teach chemistry in an online classroom. The intervention is the designing online inquiry activities to improve student learning and attitudes in online chemistry courses. The purpose of this action research dissertation is to develop at least one inquiry-based modeling activity in an online chemistry class to support conceptual understanding for students. The inquiry-based modeling activities will be based on the 5E learning cycle (Bybee, et al., 2006). The research questions addressed in this action research dissertation will be:

1. How does incorporation of 5E inquiry activities affect student performance and attitudes in an online General Chemistry 1 (CHM 151) course?

2. How do I, the teacher / researcher, understand and use inquiry activities in online chemistry classes?

In the following chapter, I will provide a detailed description of how this project was designed, enacted, and studied. I will begin with a rich description of the context, the participants, and my own positionality in order to provide the background needed to better understand the decisions I have made regarding the implementation of a 5E inquiry activity in an CHM 151 course. I will then provide an overview of the methodological design of the study and the rationale of why this design is an appropriate way to study the
impact of the 5E inquiry activity on student performance and attitudes. I will conclude this chapter with a thorough and detailed description of how I assessed my own understanding of inquiry-based teaching and my effectiveness in using inquiry-based teaching.

**Context and Participants**

The context and setting of the study was at my community college, Colleton County Community College (pseudonym, abbreviated as CCCC) located in Colleton County (pseudonym), North Carolina. In 2017, Colleton County families were identified as having a medium income less than $40000 per year and almost 20% of residents at or below the poverty line. Approximately 82% of Colleton county identify as White, 6% Black, 6% Hispanic, and 6% Asian. CCCC has a full-time equivalent enrollment of approximately 1800 students. Approximately 60% of CCCC’s students identify as female and 40% identify as male. CCCC’s enrollment in terms of race and ethnicity is representative of that of Colleton County. Two-thirds of CCCC’s students are under the age of 24.

The participants in this study were students enrolled in an online introductory college level chemistry course offered by CCCC during the spring 2021 semester. Because the course and the students were selected for sampling due to the convenience of being the only introductory college level chemistry course offered during the spring of 2021, convenience sampling was used for this study (Fraenkel, Wallen, & Hyun, 2015). All students enrolled in the spring 2021 CHM 151 course were be the participants. Attrition may occur due to students withdrawing from the course. Students may withdraw from the course due to discomfort with learning chemistry online, family
reasons, medical reasons, or employment reasons. Records were kept of student responses and student reasons for withdrawing from the course. These records allowed me to determine which students withdrew and to take their withdrawal into account when responses and data is analyzed. I will also note if students withdrew from the class because of discomfort with the 5E inquiry activity.

In terms of analysis of student demographics, thirteen students chose to participate in this study. Eight students identified as female and five identified as male. Eight students identified as being White / Caucasian and five identified as being non-White. Of those five students, two identified as Asian American, one identified as Hispanic, one identified as African American, and one identified as being multiracial. Eleven of the students had not completed a previous chemistry course and two student had completed a previous chemistry course. Finally, eight of the students were dual-enrolled high school students and five students were traditional college-age students.

**Researcher Positionality**

This section will describe my positionality towards my students and positionality towards my research as part of this dissertation. As stated earlier in this dissertation, I have 15 years of experience teaching chemistry in the community college setting. I am also a native of Colleton County whose family was at the lower end of the socio-economic spectrum. I am also graduate of a rural community college. I have normally felt very comfortable with teaching students with a similar background to myself. I attribute my professional success to the teachers I had at a community college. I feel deeply connected to my students and especially committed to my students having the same experience I had at the community college. I recognize the key role I can play in their
academic and personal growth. As an instructor, I feel more comfortable teaching in a seated, in-person lecture rather than in the online environment. However, I am also excited about the new possibilities and opportunities for teaching and learning in an online environment. I attempted my best to maintain objectivity towards rating student success and evaluating the success of online inquiry activities.

With respect to professional positionality, I was both a researcher and practitioner in this study. In terms of the practitioner role, I developed two 5E based modeling inquiry activity to use in my own online classroom. As a researcher, I analyzed my students’ outcomes and attitudes towards these activities and my own understanding of inquiry. In both the practitioner and researcher role, I deeply examined my own understanding of inquiry-based learning and how I assessed and implemented inquiry-based learning in my online classes. I was especially cautious of bias towards overvaluing my own work or not genuinely listening to concerns from students about the design of the activities.

In terms of positionality, I would fall on Herr and Anderson’s (2015) scale of being an insider in collaboration with other insiders. I implemented and assessed the results in my own classes. I always value informal student feedback. However, I was cautious of how I interpreted informal student feedback about the design of the activities. I maintained objectivity and informed students that I welcomed their genuine feedback; the students were aware that they would not be punished for giving negative feedback about the activities nor should they have felt pressured to give positive feedback.

I worked with another community college science faculty member to analyze the 5E activities. This science faculty member holds an Ed.D. in community college
leadership and uses inquiry activities in her online classes. This individual served as a peer reviewer and provided an outside perspective on online course design and allow for triangulation of data. She also assisted by being a reviewer by using the RTOP and EQUIP instruments.

I disclosed to my students that they were part of dissertation research. I wanted my students to be aware of the importance of the 5E inquiry-based activities. I believed I would have a better commitment from students if they knew that their participation would be used to help other students learn chemistry content in an online environment.

**Research Design**

There are several reasons action research is an appropriate method of study for this dissertation. First, in action research, a teacher becomes a researcher and analyzes their own practice (Efron & Ravid, 2015). In order to answer the research questions, I deeply studied my own practice and my own understanding of inquiry and how effectively I used the 5E inquiry activity to in my own course. Secondly, a teacher engaging in action research has the objectives of improvement of teaching practice, solving a local problem, and developing new teaching skills (Efron & Ravid, 2015). I sought to improve how I taught CHM 151, to solve the problem of students struggling in online chemistry courses, and to develop new skills in using inquiry in my teaching practice. Finally, a teacher using action research will put their newly developed ideas and models into use in the classroom and examine any change that results (Efron & Ravid, 2015). I analyzed results during and after the study, modified the 5E activities as needed, and monitored the change in my perception of inquiry and the changes in my students’ outcomes and attitudes towards inquiry-based learning.
This action research dissertation used a qualitative design with descriptive statistics. A key feature of qualitative research is that “the researcher is the primary instrument for data collection and analysis” (Merriam & Tisdell, 2015, p. 16). I, as both the researcher and practitioner in this study, designed my own reflection journal questions and analyzed my own responses. While I used established inquiry activities in this study, I modified the format to align with the 5E model. I used an established concept test to assess student understanding, modified the concept test to match the learning activity, analyzed the results of the concept test myself, and analyzed the student responses to the inquiry activity questions myself. I assessed my own work by using the RTOP and EQUIP methods and instruments for evaluating inquiry teaching.

Qualitative research is also used to determine how participants construct meaning to events and experiences (Merriam & Tisdell, 2015). Qualitative research was used in this study to monitor trends in student responses through documentary analysis of student responses, to code and analyze for major themes in responses, and to observe general trends in student data. Qualitative research is appropriate for this study because this study focused on how both my students and I understand and construct meaning around the use of 5E inquiry-based modeling activities in my own online classroom.

Qualitative research is both an inductive and deductive process, where data and observations are used to construct explanations, hypotheses, and theories (Creswell & Creswell, 2018). In this action research dissertation, I used my data and observations on my own reflections on inquiry-based teaching, my students’ understanding of chemistry content, and my reflections on online activity and course design to build explanations of the effectiveness of inquiry-based modeling activities in an online CHM 151 course. I
used the explanations built inductively to deductively modify and improve upon the 
inquiry-based modeling activities in possible future studies.

There are several other reasons why a qualitative approach was useful for this 
action research dissertation. In qualitative research, the researcher must be willing to take 
a questioning stance towards their own work and observations, and the researcher must 
be comfortable with ambiguity in results (Merriam & Tisdell, 2015). I deeply questioned 
my assumptions about inquiry-based modeling activities in an online course as part of 
this study. I also deeply questioned and examined the results of assessments of students’ 
understanding of course content and concepts. A qualitative researcher must be able to 
tolerate and live with ambiguity and uncertainty in results (Merriam & Tisdell, 2015). 
There was some ambiguity in the results where I believed that the inquiry activities were 
successful, yet students showed only marginal gain in core ideas and skills.

The case study design was used for an in-depth study of a particular activity, 
event, and/or individual(s) (Creswell & Creswell, 2018). Case study research is also used 
to understand a system or phenomenon where the distinction between activity or event 
and contextual setting is not distinct and when there is a bounded system or a single unit 
of study (Merriam & Tisdell, 2015). In the research described in this dissertation, I 
examined my use of 5E inquiry-based modeling activity in an online course. The 5E 
inquiry-based modeling activity served as the bounded system or single unit of study. The 
5E inquiry-based modeling activities were connected to the contextual setting of an 
instructor and students adapting to an online teaching and learning environment.
Paradigm

Merriam and Tisdell (2015) outlined four main philosophical/epistemological perspectives for qualitative research. These perspectives are positivist/post-positivist, constructionist, critical, and postmodern. This action research dissertation involved elements of post-positivist and constructionist philosophies. Post-positivist philosophy recognizes that while knowledge is subjective, evidence and reasoning can be used to evaluate claims (Merriam & Tisdell, 2015). The post-positivist philosophy in this action research dissertation evaluated the claim that inquiry based 5E activities are an effective method of teaching disciplinary practices of modeling and argument construction.

This study also featured constructionist philosophies. In the constructionist philosophy, there are multiple individuals, each with their own way to interpret an event. Each individual has their own reality and constructs that reality in their own mind (Merriam & Tisdell, 2015). In addition, the researcher does not find one correct answer; the researcher constructs the answer to a question in collaboration with the participants. One main theoretical framework of this study was cognitive constructivism. Each student constructed their understanding of information and their understanding of chemistry concepts differently in their own mind. In addition, I, as the researcher and teacher, determined how I construct and understand inquiry during the progression of the study during the weeklong 5E inquiry activity. Rather than focus on a single correct understanding of inquiry, I determined how I interpreted my experiences using inquiry-
based teaching activities and how I constructed definitions and assumptions about those inquiry-based activities in my own mind.

Another key factor related to constructivism is that the study was bound to its context (Merriam & Tisdell, 2015). While there is a national need for inquiry-based teaching in science disciplines and improvement in online learning practice, this study was highly contextually bound to the CCCC online CHM 151 course offered during the spring 2021 semester. The students were not representative of students nationwide. The direct experiences of the students enrolled in the course class was used to address the research questions. The answers to the research questions were therefore bound to the students and the instructor, and their contexts, enrolled and teaching in the CHM 151 course. I was the only instructor of the online CHM 151 course at CCCC and the results were bound to my own understanding of inquiry.

**Data Collection, Measures, Instruments, and Tools**

This section described the data collection instruments and tools used in this action research dissertation. To address the first research question, three different instruments were used. The first instrument was a student lead discussion forum based on the student responses to the questions that are part of the online inquiry activities. Students were directed to post the following information to the discussion board: three to four pieces of information that students know about the subject already (engage), observations made during the online inquiry activities (explore), summaries of their learning and the major concepts developed (explain), and the answer to an application question (extend and elaborate). Students were then directed to check each other's work and respond to at least two classmates. Perceived responses were based on what a student learned from reading
another student's work or areas of agreement or disagreement. Finally, students wrote a short reflection (evaluate) on the major concepts they learned from the activity and reading each other's forum posts.

The engage and elaborate and extend questions served to help the students make connections to everyday experiences and for students to assess their prior knowledge of the topic. The engage part of the post helped me, the instructor, understand what the students know about the topic before beginning the inquiry activity. The first set of posts due Tuesday, based on individual student observations and data, focused on cognitive constructivism in learning chemistry; students reported how they have constructed an understanding of the results of the inquiry-based activities. By reporting on how they learned chemistry concepts in the first set of forum posts, the students contributed to the cognitive presence in the course. The response to other students' posts due Wednesday focused on the social constructivism and how students learn from each other. The response posts served to aid in teaching and social presence in the online forums. The directions for these forum posts are found in Appendix A for the States of Matter Activity and Appendix B for the Gas Laws Activity.

The second instrument was the Particulate Nature of Matter Concept Test (Appendix C) by Yezierski & Birk (2006). This test was developed to assess student understanding of the states of matter and the role that energy plays in the states of matter. This test was administered online to students once they completed the forum posts based on the inquiry activities. The third instrument was a Likert-style questionnaire with some short answer questions. This instrument can be found in Appendix D. Students were asked to assess and rate how well they liked the activity, how well they feel that they
learned the chemistry content, how often they would like to see the activities used in class, and how confident they feel about learning through inquiry activities. Short answer questions focused on what students especially liked and found meaningful about the activity and what students would suggest they could change about the activity. This survey also contained a brief assessment question about their learning. Students were also be asked demographic information as part of this survey.

To address the second research question, three instruments were used. The first instrument was a self-reflection journal. In action research, a teacher becomes a researcher and studies his or her own practice for the purpose of improvement (Efron & Ravid, 2015). The self-reflection journal allowed for me to record my own assumptions about inquiry before the inquiry-based activities and my own observations of my practice after the inquiry-based activities have been completed. This self-reflection journal was a method for me to deeply study and analyze my own practice of teaching. The self-reflection questions were based on the questions developed by Rushton, Lotter, and Singer (2011) that studied how teachers understand and use inquiry in their own classrooms. The second and third instruments were used as rubrics to assess my own work. Because a goal of action research is for a teacher to study their own practice and to make improvements of their practice in the classroom (Efron & Ravid, 2015), I needed to assess my own practice and understanding of inquiry. Both instruments used to assess how I implemented the inquiry-based activities in my classroom were based on the findings of Marshall, Smart, Lotter, and Sirbu (2011). Their research indicates that two effective tools for assessing inquiry-based learning are the RTOP method and instrument (Sawada, et al., 2000) and the EQUIP method and instrument (Marshall, et al., 2011).
The RTOP instrument is described as being more holistic with more focus on interactions between students and teacher and qualitative observations. The EQUIP instrument focused on curriculum and instructional practices and assessments. The EQUIP instrument was used to verify that the curriculum and instructional practices of the inquiry-based activity are aligned with earlier goals of teaching and cognitive presence. The RTOP instrument was used to verify that the activity had effective teaching and social presence for students. Both instruments were used to determine how effectively I implemented inquiry and designed the activities to align with best practices of inquiry teaching.

**Research Procedure and Treatment**

The intervention described in this action research dissertation took place over the span of two weeks. Two inquiry-based, 5E modeling inquiry online activities were developed and implemented. The 5E inquiry-based modeling activities focused on matter, interactions, and energy. In particular, these modeling activities allowed students to explore the relationships between states of matter and energy and the gas laws. I completed my self-reflection journal questions over the weekend before beginning the inquiry activities.

The first activity, which took place Monday and Tuesday, involved using Concord Modeling Consortium’s Molecular Workbench States of Matter simulation. Students completed the States of Matter simulation and determined relationships between the chemistry core ideas of matter, interactions, and energy. As discussed previously, students completed a discussion board post activity to share their observations and conclusions with other class members. The directions for these posts are found in
Appendix A. The due date for these posts were on Tuesday. Students then responded to other students’ discussion forum posts. The responses to other students were due on Wednesday. If needed, students could revise their answers based on feedback received from classmates. The revisions were be due on Thursday. After students completed the activity, I read their discussion board posts and analyzed their posts for recurring themes, ideas, and possible misconceptions. I noted the frequency at which certain themes and ideas occurred in each post. I then completed a post-inquiry set of reflection questions after students have completed the activity.

During the next week, students followed a similar pattern related to the gas laws. Students completed the Concord Consortium modeling activities on Gas Laws and Weather Balloons on Monday and Tuesday. On Tuesday, students completed discussion forum posts based on their observations and explanations. Once again, students were directed to respond to at least two other classmates by Wednesday. On Thursday, students offered any final reflections and revisions about their learning. The directions for the forum posts for Gas Laws and Weather Balloons are found in Appendix B. On the last Thursday, the students completed the Likert survey and short response survey as well as the Particulate Nature of Matter Test. The questions for the Particulate Nature of Matter Test are found in Appendix C. The Evaluate Your Learning survey question are found in Appendix D.

After the activities were completed, I performed documentary analysis on the discussion forum posts. I determined how the students made connections to everyday life before completing the inquiry-based activities (engage). I determined the accuracy of their answers to the guided questions that were part of the tutorial and the terms and
accuracy of the explanations they developed (explore and explain). I also assessed the
types of connections they made to everyday life and how they explained everyday
observations using their learning (elaborate or extend). Finally, I noted if they reported
any changes to their learning or any deepening of understanding of the material as part of
the final post (evaluate). **Table 3.1** provides an overview of the timeline of
implementation of the inquiry methods and instruments.

I examined the overall scores for the Particulate Nature of Matter Test and
determined overall class averages. I then determined if there were frequently missed
questions and explore why those questions might have been missed. Test results were
disaggregated by gender, race-ethnicity, high school status, and previous science
background to determine any emergent trends. Finally, I observed connection of student
understanding of chemistry concepts between the discussion forum posts, short answer
questions, and test scores.

I tabulated and determined averages for the Likert-style questions that were part
of the student survey. I also coded and analyzed main themes in the short answer
questions. I looked for connection between the student responses to discussion forums
and the student responses to the Likert-style and short answer questions. These results
were also disaggregated by gender, race/ethnicity, high school status, and science
background to determine if there are connections between student classifications and
their opinions about the inquiry activities and the main themes from the short answer
questions. Finally, there was a concept question at the end of the survey; I examined the
student scores on the concept question and how the student score relates to the quality of
their discussion forum posts.
After the weeklong activities were completed, I completed the follow-up journal entries. I also completed the RTOP and EQUIP instruments. I then had a peer reviewer evaluate activities based on the RTOP and EQUIP instruments. I coded my own responses to the journal entries and track how my understanding of inquiry has changed. I met with the other science instructor and determined areas of agreement or disagreement between our RTOP and EQUIP instruments. The RTOP instrument features many areas for qualitative descriptions and observations; we compared the main observations from the RTOP instrument. I then determined any areas of agreement or disagreement between my journal entries and the results of the RTOP and EQUIP instruments. I then explored why those areas of agreement or disagreement existed. As a final step, I compared the students' responses that were part of the Likert-style and short answer questions to my own observations about the activity. Areas of agreement or disagreement were noted and I determine how and why those areas existed.

In order to maintain confidentiality, my personal pre-inquiry and post-inquiry reflection journal questions may contain specific identifying information on students and students’ performance. I kept my reflection journal in a password protected, secured electronic format. I de-identified and made anonymous any student in my self-reflection journal before reporting the final results. The student discussion forum posts and Particulate Nature of Matter Assessments were stored on CCCC’s online learning management system. This learning management system is password protected and only I and a select few college administrators would have access to the learning management system. If student responses were reported as part of the findings of this action research
dissertation, I took steps to de-identify and make anonymous the students before reporting results.

The outside science instructor reviewed the course and the activity design. As part of her access to the course, she had access to student grades or other student records. I ensured that the outside science instructor was only able to access parts of the online course that were relevant to this action research dissertation.

Pilot Studies

Several pilot studies were conducted prior to the study described in this action research dissertation. These pilot studies were conducted in online General Chemistry 1 courses in the summer and fall of 2020 semesters. These pilot studies featured an interactive activity, structured on the 5E model, and the discussion forums. Students did complete an informal, Likert scale rating and short answer questions after the completion of the pilot study. However, there were several features used for this dissertation research that were not included in the pilot studies. Aside from a summative chapter or unit test, there was no assessment at the end of the activity. I did not complete a systemic review of student responses on discussion forums. I also did not complete the reflection journal questions nor did I complete the RTOP and EQUIP instruments for the pilot study activities. The pilot studies were utilized to justify the dissertation study design based on the format of the activities and discussion forums and online evaluation activities used with students.

Summary

In this chapter, I described the context and participants in this study. I also described the research paradigm and the appropriateness of action research for this study.
The methodology describes how the activities relate to the 5E model of inquiry learning and how cognitive and social constructivism are used in the discussion forums. The methodology also describes how data was collected and processed. Chapter four provides a discussion of the data analysis and how trends from the data analysis relate to the key ideas from the literature review in chapter two. Chapter Five describes the action research plan and implications for future study based on the trends observed in data analysis.
Table 3.1 – Timeline of Implementation

<table>
<thead>
<tr>
<th>Prior to use of 5E Inquiry Activities</th>
<th>I completed pre-inquiry journal entries and reflections</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Week 1</strong></td>
<td>Monday to Tuesday: Students completed &quot;States of Matter&quot; answers to engage, explore, explain, and elaborate-extend questions to discussion forum. Wednesday: Students posted responses to other students about similarities, and differences in original discussion forum post. Thursday: Students completed an evaluate response forum post.</td>
</tr>
<tr>
<td><strong>During Weekend</strong></td>
<td>I completed first part of post-inquiry journal reflection questions. I coded and analyze student forum posts for week 1.</td>
</tr>
<tr>
<td><strong>Week 2</strong></td>
<td>Monday to Tuesday: Students completed &quot;Gas Laws&quot; activity and posted answers to engage, explore, explain, and elaborate-extend questions to discussion forum. Wednesday: Students posted responses to other students about similarities, and differences in original discussion forum post. Thursday: Students completed an evaluate response forum post. Students completed &quot;Particulate Nature of Matter&quot; concept test. Students completed &quot;Evaluate Your Learning&quot; overall survey of attitudes.</td>
</tr>
<tr>
<td><strong>After use of 5E Inquiry Activities</strong></td>
<td>I completed the second set of post-inquiry journal entries. Peer Reviewer and I completed RTOP and EQUIP Instruments. I coded and analyzed forum posts for Week 2.</td>
</tr>
</tbody>
</table>
CHAPTER 4
RESULTS AND DISCUSSION

In this chapter, data related to the two research questions is discussed and analyzed. First, data examining student outcomes, based on discussion forums, the conceptual test, and a student survey are analyzed and compared for both the States of Matter and the Gas Laws activities. Then, student attitudes towards the inquiry activities are examined using discussion forums and the student survey. I also examine my own understanding of inquiry and how I used inquiry in the online chemistry class by analyzing and comparing results from my journal entries and the RTOP and EQUIP instruments. Finally, this chapter concludes by comparing student outcomes, student attitudes, and my own understanding of inquiry with each other. Table 4.1 provides an overview of how the inquiry activities and research instruments were used during this study.

Research Question 1 – Student Learning Outcomes on States of Matter Activities

As stated in Chapter 3, students were directed to complete the Concord Consortium’s States of Matter inquiry activities and simulations. Students were directed to post three to four initial thoughts about states of matter (engage), their observations and explanations as guided by the inquiry activities (explore and explain), and an application to everyday life (extend / elaborate) on a Tuesday. On Wednesday, students
read each other’s discussion forums and posted responses to two other students. On Thursday, students reflected on and summarized their learning (evaluate). The directions for these forum posts can be found in Appendix A. I analyzed and coded these student responses for major themes and trends.

Four students did not post any initial thoughts as part of the engage prompt. The remaining students' initial thoughts were simple definitions of solids, liquids, and gases. One student posted correct prior knowledge about how attractions between particles determine state of matter. One student posted prior knowledge about the relative densities of solids, liquids, and gases. Because the online inquiry simulation had a feature where students could check their answers, all students had the explore questions correct. All students were able to answer the explain questions correctly. The explore or elaborate step featured the jar lid, lava lamp, rattling window, and ring and sphere problems. In the jar lid problem, students were asked to explain why using hot water on a stuck jar lid loosened the lid. In the lava lamp problem, students were asked to explain why the "lava" in a lava lamp rose and sank. In the rattling window problem, students were asked to explain why windows "rattle" with wind in the wintertime. In the sphere and ring demonstration, students viewed a video where a sphere was able to fit into a ring. Once the sphere was heated, the sphere could not fit into the ring.

When asked to find applications to everyday life as part of the explore or elaborate step, six students chose the jar lid problem, five students chose the lava lamp problem, two chose the rattling window problem, and three chose to explain the ring and sphere demo. Most students correctly explained their chosen application, however one stated that atoms expand while heated. This misconception will become important later in
the data analysis. Several students made the connection to the jar lid about what they had seen their grandmothers doing to loosen a jar lid. Another student asked an independent question about how the state change of sublimation related to their experience in screen printing.

When asked to reflect on their learning, eight of the students felt they had learned from the states of matter activity. Five stated that they did not feel like they had learned. However, of the students that stated that they feel like they had not learned from the inquiry activity, one of the students stated that the activities had made them think more about everyday life. One stated that they were more curious about the relationship between energy, attractions, and states of matter. One student stated that the inquiry activities were a good refresher of prior knowledge. Based on these comments, I believe that while they might not have thought that they learned anything new, those three students did obtain a greater awareness of how the chemistry concepts of energy and states of matter related to everyday experience. Table 4.2 summarizes some of the main student responses in the forum posts and instructor observations and comments.

As a method of assessing student learning, a modified version of the Particulate Nature of Matter test (Yezierski & Birk, 2006) was given on the Thursday at the end of the second week of implementation. This conceptual test is designed to measure students' comprehension of the differences between solids, liquids, and gases and how the particulate nature of matter relates to these states. Of the thirteen students that completed the concept test, the average score was a 69. While a modified version of this concept test was given as part of this dissertation research, the original studies noted an average score of 70 after students had completed a unit on the study of states of matter. Analysis of the
test questions used in this research revealed that students scored the highest on the questions that asked students to compare the relative movement of particles in solids, liquids, and gases. Several questions in the inquiry simulations in the engage and explain steps asked students to observe models of the movement and make summaries of their observations. Because of the direct modeling, observation, and summaries, and the connection of scores on the concept test, I felt that students have learned the relationships between energy, particle movement, and states of matter.

However, students commonly missed questions regarding the relative volume and mass of particles in the solid, liquid, and gas state. As part of the discussion forum, most student correctly used the application problems to realize that the transition from solid to liquid to gas causes volume to increase and density to decrease. Those students also correctly realized the relationship between temperature and volume in the discussion forums, as evidenced by the number of students that could correctly explain the jar lid and lava lamp analogy. However, those students did not make the connection that while the total volume that the particles occupies changes; the actual volume of the particles does not change. Only the space in between the particles will change with temperature. The students might have understood the general relationships and trends for temperature and states of matter but were unable to make the connection to the particles that make up states of matter.

Further analysis of student scores shows interesting trends between student demographics and student scores. As part of a student survey, students were asked to identify their gender. Eight students responded as female and five students responded as male. Both male and female students scored an average of 69 on the conceptual test.
There seemed to be no major difference in score. However, two female students scored a 100 on the concept test. The original study that developed and used the concept test noted that before the original study was completed, female students scored lower than male students on a pre-test. However, after the treatment in the original study, female students scored roughly equally to male students. Yezierski and Birk (2006) hypothesized that the reason for a gain in the scores of female students is due to the spatial reasoning skills being taught and utilized as part of their intervention. However, I did not have students complete a pre-test and I have no information about possible gain in understanding about states of matter due to gender.

In examining students based on race and ethnicity data, I only separated scores by students who identified as White versus non-White. Based on the small sample size, I did not feel comfortable further dis-aggregating data into specific racial and ethnic groups. The non-White students had an average score of 58 on the concept test and the White students had an average score of 75. This is a disappointing result in the difference between the scores of the different groups in that one of the goals of this study was to determine if inquiry methods were effective for diverse learners. However, the absence of a pre-test does not give information if diverse learners had a significant gain in knowledge about states of matter. The method of assessment of using a primarily multiple-choice test may also not have been an effective method to assess the learning of diverse students.

Other student groups of interest are dual enrolled high school students and students that have not completed a previous chemistry course. My prior observations were that high school students and students who have not had any previous high school
chemistry classes struggled with content and had low motivation to learn chemistry. One original intent of this study was to explore a method to increase the learning outcomes and motivation of those students. When separated by student type (eight high school versus five traditional college), the average score on the Particulate Nature of Matter concept test of the dual-enrolled high school students was 62 and the average score of the traditional college students was 78. Based on the evaluate forum posts, six out of the eight high school students reported that they felt they learned chemistry, however, their perceptions do not align with their student scores. Perhaps the type of questions or the wording of the questions on the conceptual test were not appropriate for high school students. In a future study, a pre-test would be helpful to understand the level of knowledge of states of matter that students enter the class with to determine any gains in knowledge during the activity. One other factor could be that the high school students did have a significant gain in knowledge about states of matter, but the gain could not be measured due to lack of a pre-test.

When students were separated by chemistry background (eleven without a previous class and two with a previous class), the average score on the Particulate Nature of Matter Test for those students who had not completed a previous chemistry class was 67 and the average score of those students who had completed a previous chemistry class was 77. Based on analysis of evaluate discussion forum posts, all the students who had not completed a previous chemistry course reported that they felt they had learned chemistry by completing the States of Matter activities. However, they had lower scores than those who had completed a previous chemistry class. Perhaps students need more experience in chemistry classes to read and understand chemistry test questions. Once
again, use of a pre-test would have been helpful to determine relative gains of knowledge between both groups. It could be that the students without a previous chemistry course did have significant gains in knowledge about states of matter. Further methods of exploring the relationship between gender, race / ethnicity, and student background will be developed and discussed as part of chapter 5.

**Research Question 1 – Student Learning Outcomes on Gases Activities**

The results are even more ambiguous when data from the Gas Laws activity are analyzed. When asked to engage and state some previous knowledge about gases, most students correctly restated and summarized what they had learned in the previous activity. One student asked a question about how the properties of gases related to the atmosphere and another student used several examples related to cooking spray. When asked to state an original definition of pressure, eleven students stated an original definition; all those original definitions described pressure solely in terms of force. One student made an analogy to placing pressure (force) on a wound to stop bleeding. Once again, student responses to the explore and explain questions were mainly correct due to the self-check feature available for students as part of the activity.

After completion of the activity, students were asked to choose a gas law and explain an everyday observation based on their chosen gas law. The four observations students could explain were breathings, tire size as a function of temperature, exploding aerosol cans, and a demonstration video of a metal can being crushed by being placed in ice water. Four students chose to explain Boyle’s Law (relationship between pressure and volume and how breathing works); one student did not make the connection between Boyle’s Law and breathing; and the other restated the relationship backwards. Three
students chose Charles’s Law (relationship between volume and temperature and tire size on cool and warm days) and all three correctly explained the relationship. Two of those students explained the relationship in terms of a tire or balloon changing size based on temperature while one related to temperature and size of breaths. Only one student chose to explain Gay-Lussac’s Law (relationship between pressure and temperature and explosions in a fire) and that student correctly explained the relationship and why an aerosol cannister explodes in a fire. Four students chose to explain the can crush demo (relationship between pressure inside and outside a can), and only two of those students were correctly able to explain the relationship. One student mis-read the assignment and did not pick a gas law to explain.

Twelve out of the thirteen students did state they felt that they had learned more about gases as part of their evaluate post. Most students stated that they felt they had learned the relationships between temperature, volume, and pressure as part of the activity. However, when asked to re-evaluate their definition of pressure, students still solely defined pressure in terms of force of collisions. Even though several students chose Boyle's Law as part of the extend/elaborate step and other students responded that they liked the explanation, no student took the volume or area of the container into account when explaining pressure. **Table 4.3** summarizes the results of the Gas Laws activity.

The lack of student understanding between the interactive activities and pressure definition is seen in the results of the "Evaluate Your Learning" student survey. This survey will be described more in-depth later in this chapter. As part of the student survey, students were posed a question where they had the same amount of gas at different volumes and temperatures and students were asked to pick which gas sample would have
the greatest pressure. Of the thirteen students that completed the survey, twelve were able to identify that the gas with the higher temperature would have the higher pressure. Of those twelve, ten were able to offer a correct explanation of how a higher temperature leads to a higher pressure. While only one student chose to explain Gay-Lussac's Law as part of the Gas Laws activities, it seems that students were able to learn the relationship between pressure and temperature by completion of the activities or reading the one discussion forum post.

However, as part of the question on the student survey, students were also asked to identify which volume of a gas would give the greatest pressure. Only five out of the thirteen students that completed the survey identified that the gas with the smaller volume would have the greater pressure (Boyle's Law). Of those five students, only three were able to offer an explanation as to why decreasing the volume would increase the gas pressure. Eight of the thirteen students thought the gas with the larger volume would have the greater pressure. Of those eight students six stated that the larger volume would contain more gas particles. While part of the simulation showed that increasing the number of particles would also increase gas pressure, the question explicitly stated that the amount of gas was the same in all the examples. It could be viewed as a weakness of the activity that students did not properly read the question or understand the Boyle's Law relationship. However, these students did make a connection between amount of gas and pressure. Therefore, it seems that some learning about the properties of gases did occur as part of this activity, but there were still gaps and misconceptions in student knowledge. Further reasons for the students’ lack of understanding and misconceptions related to gas properties and methods of clarifying those misconceptions will further be discussed in
Chapter 5. Table 4.4 summarizes the results of the survey question concerning the gas laws.

One of the overall aims of this study is to improve outcomes and attitudes for diverse students. Discussion forum posts for the States of Matter activity were further analyzed to determine common themes that emerged for students of color. Of the five students in the class that identified as being non-white, three out of the five stated that they felt like they had learned as part of this activity. One stated that she felt like she did not learn anything new but had a greater awareness and more curiosity about the subject. One did not complete a final evaluate forum post. In addition, one student specifically stated that she liked seeing a demonstration performed and that it "blew her mind." The student comment about being more curious about the world around her and the student comment about enjoying a demonstration indicate that these diverse students are beginning to make connections between the course content and their everyday experiences.

In the analysis of discussion forum posts related to the Gas Laws activity, similar results are observed for racially and ethnically diverse students. Two students made excellent connections to everyday life, one using pressurized cooking spray and the other using basketballs to illustrate the relationships between volume and temperature. Another student found the demonstration video very helpful to visualize the chemistry taking place. Four out of the five stated they had a change in their understanding of the properties of gases. Once again, based on discussion forum posts, I feel that these inquiry methods, especially with an emphasis on the starting engage and ending elaborate/extend questions are helpful for students of color.
Research Question One – Student Attitudes Towards Inquiry

As stated previously, students were asked to evaluate if they felt they had learned anything as part of the States of Matter activity. Eight out of thirteen students stated that they felt they had learned the material. Of the five that stated they felt that they had not learned anything, one stated the activity was a good refresher, one stated they were more curious about the natural world and relationships they had seen as part of the activity, and one stated the activity caused them to think more about chemistry. As part of the Gas Laws activities, students were asked to evaluate their learning and state if they felt they had learned the material. Twelve out of the thirteen students did state they had learned the material. Based on these discussion forums, it seems that students have a positive attitude towards learning chemistry by inquiry methods.

After both inquiry activities were completed, students completed a survey titled "Evaluate Your Learning." This survey can be found as Appendix D. As part of this student survey, students were asked Likert-scaled questions about their perceptions of using the inquiry method. Table 4.5 summarizes the questions and numbers of responses. Question one asked students to rate how well they liked using both of the inquiry activities. Question two asked students to rate how they believed they learned from these activities. Question three asked students to identify how often they would want to use these activities. Question four asked students to rate the confidence in learning from these activities. A response of one indicates a low interest or never and a response of five indicates a high interest or always.

A review of the student responses shows that twelve out of thirteen students reported a three or higher for liking the activities. All thirteen feel like they had learned
from the activities. Eleven out of thirteen would want to use the activities again. Eleven out of thirteen had confidence learning in these activities. One student's ratings for the four questions were 1, 3, 1, and 3; this student's low ratings will be explored further in this section. Other reasons for ratings two or lower will also be discussed later. When this data was separated by student gender, the ratings for female students were 3.6, 3.8, 3.5, and 3.4. The ratings for male students were 3.8, 3.6, 3.6, and 3.8. Female students rated the "Rank how well you believed you learned from these activities" slightly higher than male students. However, male students rated the other questions higher than the female students. In particular, the question that asked, "What is your confidence in learning from the activities?" was rated lower by females than by males. This result is disappointing in that it appears that female students are able to learn from these activities yet still have low confidence in their ability to learn. Unfortunately, this reflects trends of female students demonstrating excellence in science fields (Wang & Degol, 2013) yet being discouraged in their scientific studies and not further pursuing science degrees and careers (Sadler, Sonnert, Hazari, & Tai, 2012).

As stated previously, there were very small numbers of students that identified as Asian American, African American / Black, and Hispanic. In disaggregating the scores based on if the student identified as White or non-White, the average ratings of the White students were 4.0, 3.7, 3.7, and 3.6. Non-white / students of color had average ratings of 3.6, 3.6, 3.2, and 3.4. While I am pleased that students of color had average ratings higher than a 3.0, indicating overall positive attitudes towards the inquiry activities, I am disappointed that the averages are less than those of White students. In order to better meet the needs of diverse students, perhaps a series of inquiry activities are needed to
increase their confidence in learning and comfort using these activities. Methods of revision of these activities to better meet the needs of diverse students will be explored in chapter five.

In disaggregating the student survey results based on whether the student is dual enrolled in high school or not, the high school students all had average ratings lower than the traditional college age students. The ratings for high school students were 3.5, 3.5, 3.4, and 3.2. The rating for the traditional college students were 3.8, 3.8, 4.0, and 3.8. This is a disappointing result in that one original purpose of this dissertation research was to find a teaching method that would better appeal to high school students and increase their motivation towards learning chemistry. In disaggregating the student survey results based on the student having a previous chemistry class, students that had not had a previous chemistry class consistently had lower responses than students that had completed a previous chemistry class. The average ratings of the students without a previous chemistry class were 3.6, 3.6, 3.4, and 3.4. The average ratings of the students with a previous chemistry class were 4.0, 4.0, 4.0, and 4.0. Another original purpose of this dissertation was to determine if inquiry was an effective method for teaching students without a previous chemistry class. However, the average responses were still greater than three for both the high school student and the no previous chemistry class student groups. The inquiry method may be effective for teaching these student groups, but more work may be needed to increase those groups' interest and self-confidence in learning chemistry. Further discussion of these results will be given in Chapter 5. Table 4.6 lists the ratings dis-aggregated by student group.
As part of the student survey, students were asked to identify one thing they liked about the activities in a short answer question. Several students actually listed more than one thing they liked about the activities. Six out of the thirteen responses focused on the fact that students liked the visual aspects of learning chemistry by the inquiry simulations. In related comments, one student commented that they liked the hands-on learning aspect and two liked the engagement with the interactive inquiry activities. Steve (pseudonym), a white male, traditionally college age student without a previous chemistry course stated "I liked the visuals of what was happening on a molecular level. . . . It was very easy to see and understand what was happening and why."

Comments related to instructional design included that the activities were easy to learn from, allowed for students to test their own knowledge, and were self-explanatory. Other comments suggested that students liked that the activities were short and allowed for students to learn at their own pace. As an example, Elsa (pseudonym), a white female high-school student who had not completed a previous chemistry class, stated that "One thing that I liked about these activities was that they didn't take long to do, and that I was able to actually learn something from them!"

Students were also asked about one part of the activities that they would want to be changed if the activities were used in the future. Two students responded that there was nothing they would have wanted to have done differently. Several responses related to the timing and pace of the activities. One stated that they felt there were too many activities to complete, one stated that the activities were too short, and two stated they felt they needed more time to complete the activities. One student did not like the setup of the discussion forum to post and read answers. This student, Phillip(pseudonym), a white
male, traditional college student who had completed a previous chemistry class stated "I thought that responding was more of a hassle than a benefit being that we all did the same assignment." Related to the discussion forum posts for feedback, two students asked for a better system to check their answers than simply posting and reading others' responses. Two students had technical issues with the online activities. Two students stated they felt like they learned better in class and one stated that they did not like completing this activity alone. Methods to improve the setup of the discussion forums, methods of improving feedback to students, and methods of improving the alone activities will be discussed further in chapter 5 with next steps.

As stated in the section on student survey scores, there was one student that rated these activities very low. This student was Ana (pseudonym), who self-identified as an 18 year old, female Hispanic student. In this student's responses to the survey questions, Ana stated that she did not like these activities "because I did not do well learning on my own and figuring out the activity. . . I personally feel like someone teaching me in front would have felt better." In determining a reason for Ana's low ratings of the activities, Lee and Buxton’s (2010) study noted that some students from racial and ethnic minority groups are uncomfortable learning science by the inquiry method. They stated that a short introductory lecture before the inquiry activity by the instructor may be a better method for teaching certain diverse learners. In addition, they also stated that some racial and ethnic minority groups are uncomfortable being questioned by a teacher, uncomfortable about asking questions back to the teacher, and uncomfortable discussing, often seen as arguing, with other students about their observations and interpretations. As the teacher, I could have done a better job in explaining to students that it was acceptable to agree or
disagree with each other, and I could have given students better guidelines for engaging on the discussion forum. Guidelines for discussion forum activities will be explained more in depth in Chapter 5.

However, elsewhere in the survey responses, Ana also stated the fact that she liked that she could "write out" her responses ahead of time. Evidence supports that inquiry can assist ELL in that ELL students have a context to learn language, that students can communicate orally, pictorially, and in writing, and that inquiry assists in developing writing, grammar, and vocabulary skills (Amaral, Garrison, & Klentschy, 2002; Warren & Rosenbury, 2008). Perhaps Ana's comment of liking that she could write out her answers ahead of time before having to report them showed that she was able to improve her communication skills, grammar, and science vocabulary. In a previous pilot study, Glendy (pseudonym), also a self-identified female Hispanic student who was an English language learner, made the comment that she liked the discussion board format for several reasons. First, she liked the format because she had time to think about and process her answer; in a traditional lecture format, she stated that she felt like she never had time to properly think about and phrase her answer. Secondly, she liked the fact she could check her work (and perhaps her grammar and vocabulary) by checking the work of other students. Finally, she especially liked the discussion forums because she felt that other students listened to her and respected her work; in a traditional class group work, she stated that she felt that other students did not pay attention to her contributions.

In further analysis of student comments on the survey by non-white students, three out of the five non-White students identified that they liked these activities because they were visual. Other positive comments included that students liked that they could
learn at their own pace, they liked the applications to everyday life, and that they could write out answers ahead of time. Suggestions for improvements included two comments of needing more time to complete and two comments of needing more feedback and desire to work with an instructor. I am pleased that students are making connections to everyday life. I am also encouraged that the visual nature of these activities appeals to diverse learners.

In Chapter 1, the concept of presence in the online course was discussed as a consideration for design of the activities and why students did not learn effectively by traditional lectures in an online course. The student comments that emphasize hands-on and engaging nature of the activities and that the activities made it easy to learn, allowed for them to test their own knowledge, and were self-explanatory demonstrate relationships to cognitive and teaching presence in the class. These comments indicate an improvement in teaching and cognitive presence for both students and for me, as the instructor.

**Research Question 2 – My Inquiry Journal**

As a method of tracking my own understanding of inquiry, I used an inquiry journal with questions based on the questions developed by Rushton, Lotter, and Singer (2011). In this study, teachers participated in a two-week inquiry workshop and completed pre-workshop questions and then completed questions during and after the workshop. Teachers also completed these reflection questions after using inquiry methods in their own classrooms. I completed the pre-inquiry questions before my students started the inquiry activities. I completed one set after the States of Matter Activity and one set after students completed the Gas Laws activities. I then examined
major trends in my responses and determined how this correlated to the responses of my students in forum posts and survey questions.

One main theme of the pre-inquiry questions was my comfort with the traditional lecture method. I had mentioned this comfort as part of my background in Chapter 1 and how I felt like my comfort with the traditional lecture method, both in-person and online, lead to students struggling and the problem of practice. However, I also noticed that one component I like about in-person learning is that I can ascertain feedback regarding students’ level of learning. I can check to see if a student is understanding the material by an “ah-ha!” look in their eye, a stated positive comment, or a nod of the head. One hesitation I had about teaching inquiry online was the absence of knowing if and how students are actually learning the content.

In examining my own definition of inquiry and how I use inquiry in the classroom or laboratory, I noticed a connection to the Adkins-Karplus model. My initial definition of inquiry places the hands-on experimentation first, then the analysis, and finally the explanation. In some in-person inquiry activities, I circulate to small groups and help them make the connections, help them analyze data, and help them develop their explanations. Even when I completed traditional lectures in-person, my journal questions reveal that I try to guide students in small steps to think about what might be coming next in the lecture.

I believe that science can be taught by inquiry methods, because that is the nature of science! However, as part of the journal, I also reflected on that I had problems with teaching with inquiry in the traditional lecture, in-person, classroom. As stated in chapter 2, the Farrell, Moog, and Spencer (1999) study developed a workbook of inquiry
activities that I have tried to use in traditional in-person classes. The workbook based on Moog, Farrell, and Spencer did not make a good case for why students needed to know a concept; the activities did not make connections to everyday life; and the activities did not feature hands-on demonstrations or laboratory activities. I also expressed hesitations about group work. My hesitation about group work is in finding better methods to assign students to groups, to manage tasks in groups, and to increase individual accountability in groups. The hesitation about the design of inquiry and the time needed for inquiry is an important part of recommendations for future study in Chapter 5.

A journal question asked to reflect on and respond to how I see science being found in everyday life. I responded that “Science is everywhere! Science is curiosity, asking questions, and exploring relationships in the world around me. The rules of the game learned in chemistry provide a series of tools and a lens to which to ask and explore the natural world.” In examining my response to strengths as a teacher, many students like my enthusiasm for the subject matter. One of my goals is to impart my enthusiasm for science, curiosity, asking questions, and exploring relationships to my students. An effective method for completion of this goal would be structured inquiry activities. As stated in chapter 1 and related to the concept of CRP, I want my students to also make connections to their everyday lives and see how chemistry and science can be used in relationship to their unique experiences. However, I want to be sensitive to the examples I use in that I do not want my students to feel excluded because I use an example or connection that is not relevant to them.

One final question in the reflection journal related to how I use reflection in modifying assignments and activities. I usually know when to modify a lecture or inquiry
activity when I see a puzzled look on a student’s face or I receive several similar questions. I also know to modify an assignment or lecture when students consistently miss questions on a quiz or test. One benefit of the way I use lecture, as I explained in chapter 1 and earlier in this section about how I use inquiry, is that I can constantly give students feedback and revise teaching methods as needed. In an online activity, my hesitation is that I will lose the ability to revise as needed and also give appropriate feedback to my students.

There are several important points in responses after the States of Matter inquiry activity. My first observation is that I was nervous letting the students learn on their own in the online setting and giving students freedom; however, the students seemed to have learned some of the content without my direct intervention. I also noticed that I liked the hands-on nature of the activity. I believe my students found meaningful connections to everyday life, for example the properties of water and rocks that were part of the States of Matter activity. For that activity, my understanding of inquiry did not change; I believe that the students manipulated the simulations and made observations before summarizing or being told the correct answer. I did note that I liked the structure of the 5E cycle; I was hesitant to use inquiry because of mixed results using the Farrell, Moog, and Spencer (1999) workbook and their format of inquiry activities. I felt that the 5E model gave the inquiry activity more structure, purpose, and direction. While I was hesitant about not being able to see those “ah-ha!” moments in students, I was able to observe good discussions on the discussion forum. I could still see their enthusiasm and interest based on discussion board results.
I had less confident results with the Gas Laws inquiry activity. I did not feel that I had a meaningful experience as a teacher. I noted that, as part of the extend/elaborate step, I could have had students find the everyday examples first, then explain the example using the appropriate observation from the simulation and then use the appropriate gas law. This structure itself is more aligned with the engage, explore, and explain parts of the 5E model and the exploration, invention, and discovery model proposed by Adkins and Karplus. Perhaps if I were to change the order of tasks and process as part of the extend and elaborate section, I would have had a more meaningful experience as an instructor. I do believe that my students had a meaningful experience watching the “crush the can” video and explaining the video using the gas laws. The crush the can demo can easily be completed at home and provides students with a surprising observation of a can being crushed by ice water. I also noted that I have not been able complete many labs and demos while teaching online; this video helped my students see an everyday application of the gas laws and gas properties.

In reflecting on how my understanding of inquiry changed, I noted that I could have done more as a teacher. One flaw I noticed was that I stepped back too much from the activity and from the discussions. I had designed the activities for students to complete independently at their own pace and time. Most students expect that type of flexibility in an online course. Because students were completing parts of the activity at different times and the Tuesday, Wednesday, then Thursday format, I was not able to meaningfully read or give individual feedback on the forum posts. I believe I could have found more examples and built the extend and elaborate steps more around some of the examples students gave as part of their initial engage post. If I had more time to process
and read the discussion forum posts, I believe that I also could have provided more clarity about Boyle’s Law and clarified relationships between gas pressure and gas volume. While I thought the activity itself and the questions directly associated with the activity were well done and lead to teaching and cognitive presence, I could have been more present myself as a teacher and done more to gently question students to improve their understanding. With more presence and guidance on the discussion forums, I could have done better in the back-and-forth nature of student-teacher feedback and interactions that are part of both the cognitive constructivist and social constructivist model of learning.

There is a connection between my observations in my reflection journal that I did not give enough feedback to the student comments and that they wanted more feedback during some of the activities. I feel that we both realized that I could have done more with the feedback part of the inquiry activity. Future uses of the inquiry activities will be structured so that I have time to give adequate feedback to students and to adapt examples to what students initially bring up as part of the explore, initial thoughts, or prior knowledge step, all of which are examples of utilizing CRP as a fundamental instructional strategy.

**Research Question 2 – RTOP Instrument**

As stated previously, the RTOP instrument was completed by both me and a peer reviewer after the inquiry activity was completed. We compared both numerical ratings and comments to determine areas of agreement or disagreement. In the first section of the RTOP instrument, we rated the first three components of prior knowledge, engagement in a learning community, and exploration before presentation as high. I rated myself slightly lower on alternate modes of investigation and student directed activities. The peer
reviewer noted that students were encouraged to reflect on the discussion forum posts and that student comments on the forum indicated engagement. I noted that there were very direct instructions from the simulations and there was not an “alternate” way of completing the simulation. I also noted that the student directed activities were not part of the explore or explain steps, but part of the elaborate or extend step.

In the instructional methods section, we both rated all these points high. In comparing comments, we commented on the connections made to other disciplines and areas of the students’ lives. However, we had differences related to the procedural knowledge sections. Upon completion of the activities, I realized that I could have had students complete and upload a drawing of what was taking place at the particle level as part of the explain, elaborate or extend, or the evaluate steps. The peer reviewer noted that the simulations did ask the students to make predictions, but there was no formal proposing and testing of a hypothesis. The peer reviewer also noted that there was no assessment of the procedures required to complete the activity. I noted that more work should be completed to determine the accuracy of the simulations themselves. In a different activity that was part of a pilot study, I asked students to consider and reflect on one shortcoming or limitation of the activity related to the accuracy of the models and simulations presented to the students. To improve on assessment of procedures in future studies, I could have an elaborate/extend question for students to consider, propose, and test a hypothesis on their own and report their results back to the class. I could have one of the evaluate questions ask the students to consider what a shortcoming of the simulation might be. For example, the States of Matter showed all particles as spheres and did not distinguish between the structure of atoms and molecules and how both might
(or might not) change during phase changes. I noted that reflection, rigor, constructive critique, and the challenging of ideas were present between students as part of the discussion forum. However, I could have improved the reflection, constructive criticism, and challenging of ideas in my interactions with students.

The peer reviewer and I had some differences in the Classroom Culture section of the RTOP instrument. I rated the statement, “Students were involved in the communication of their ideas to others using a variety of means and media” as a two, but the peer reviewer rated this as a four. My observation and reflection was that students only communicated by using the discussion forums. The peer reviewer noted that “Students used discussion forum . . . Multiple means of communication in online course would have been distracting for students.” I agree with the peer reviewer on this point; I believe that students would be confused if they had to communicate by using discussion forum, text messages, videos, and email. However, there is an idea to expand on this shortcoming that I will detail in chapter 5. We also disagreed on the statement, “The teacher’s questions triggered divergent modes of thinking.” She rated a three and I rated that a four. While I may not have been asking the questions directly to students, my intent was that the tutorial simulations and elaborate or extend questions would promote divergent thinking in my students. This also relates to my students’ observations of needing more feedback and my noticing of my absence on the discussion forums. More presence on my part in the discussion forums would allow me to ask more questions of students to promote divergent methods of thinking and suggesting to students' ways to test their divergent modes results. We both noted there was a high proportion of student talk. However, we had major differences with the statement, “Student questions and
comments often determined the focus and direction of classroom discourse.” She rated that statement as a four and I rated that statement as a two. My comment was that I could have allowed more flexibility for students to find their own extend or elaborate applications in the discussion forums. I feel that I could make a general statement of ideas for extensions and elaboration, but also encourage students to find and explain their own application of the content. I could have also used the students' initial experiences as part of the engage step to better craft direction and focus of the elaborate or extend questions.

In further analysis of the classroom culture, communication, and relationships section, we both rated the climate of respect, active participation, and encouragement of alternate explanations as high. We both rated the patience factor as low in that I did not actively participate in the discussion forum. We both rated the statement, “The teacher acted as a resource person, working to support and enhance student investigations” as very low. My comment was that I knew there is room for growth in giving feedback at several points in the discussion forum, but the Tuesday, Wednesday, Thursday structure of the activities was limiting my feedback. I did give students brief, informal feedback through a video, but I did not make listening to the feedback mandatory nor did I emphasize the importance of the feedback in the video. Finally, we both rated the statement about the teacher being a listener as low. I felt that I was a good listener but that I lurked in the background too much. The peer reviewer noted that it was difficult to gauge how I assessed or participated in the discussion forums.

We both noted major recurring themes of the hands-on nature of the activity, the student participation in the discussion forums, and the lack of my participation in the forums. While we were both complimentary of the hands-on nature of the activity, we
both believed more could be done to have students generate and test hypotheses through the activity. We both noted many positive aspects of students communicating with each other through the discussion forums. We also noted that I had a lack of participation in the forums. One conclusion that I can draw from examining the major themes and scores from the RTOP instrument is that there is agreement between my observations and students observations about the hands-on and visual nature of the activities being a strength of the activities. In examining the results of some student comments, my self-reflection journal, and the RTOP instrument, one conclusion I can draw is that I need to be more present in the discussion forms and offer more short feedback and questions to guide students in their discussions. Again, a technique to better address this shortcoming will be offered in Chapter 5.

**Research Question 2 – EQUIP Instrument**

In this section, I will describe the results of the EQUIP instrument evaluations by both myself and the peer reviewer. I will then make connections between the results of the EQUIP instrument, student evaluations, my inquiry journal, and the RTOP instrument results. In terms of the instructional strategies section, both the peer reviewer and I rated the inquiry activities as a four for general instructional strategies and the order of instruction. However, we had a difference in the role of the instructor. While we both rated my actions in the activities as a four, I questioned if I was an effective instructor in prompting the students for questions or if the simulation was acting as the instructor. The peer reviewer was complimentary on the fact that I acted as facilitator in that I started discussions. The peer reviewer noted that I did not effectively interact with students in the discussion forums. I found these results similar to the observations from the RTOP
instrument related to my lack of participation and dialogue with students in the discussion forums. Both these results help reveal that a shortcoming in my implementation of the activity and my understanding of inquiry is the role of the instructor to facilitate dialogue in the online forums. We both rated the student roles of participation and activity as very high and we both rated the depth of knowledge acquisition as high.

The next section of the EQUIP instrument evaluates the discourse factors in the activities. We both rated the level of questions, complexity of questions, and questioning ecology as high. However, I commented regarding the complexity of questions that “Students responded to each other, but I don't know if students actually criticized each other’s responses. How can I prompt students to better critique in the future?” I believe that some of the earlier comments from students that were not pleased with the discussion forum format and the depth of the discussion forum posts align with my observation that while responses were taking place, the responses and questions between students may not have been deep or effective questions. In addition, improving the structure of discussion forum could also improve the language and argument skills of English language learners. A method for improving discussion forums will be described as part of chapter five.

The peer reviewer rated the communication patterns as a four; I rated the communication patterns as a two. I made the comment that I lead a large amount of discussion by giving the students very structured questions at the start of the activity and that I felt that the communication was extensively controlled by me, the teacher. The peer reviewer felt that the student communication with each other in the forums was mainly self-guided. I could have done better by adjusting the extend and elaborate questions
based on initial student engagement questions. This observation is also mirrored in the observation and conclusions from the RTOP instrument in the need to adjust the elaborate and extend questions based on initial student knowledge. I also could do better in letting students have more freedom and flexibility in selecting elaborate and extend questions.

We both rated the next section and question about classroom interaction as a two. We both noted that, once the activities were started, no adjustments or flexibility for the activities were made. I also offered the additional comment that students need more time to complete the response. The comment and observation of mine also relates to the student comments that they felt they needed more time to complete the activities. Methods of adjustments to the original procedure to allow for more feedback and time to complete the activity will be given in Chapter 5.

In the assessment factors, both the external researcher and I noted that while there was good assessment of prior knowledge, there was no adjustment of instruction based on the prior knowledge. We also rated the activities high on conceptual development and student reflections. Her comments on the student reflections stated that I started the discussions and reflections but did not interact with students. However, I thought that the questions that were part of the activities did a good job in having students reflect as they completed the activities. I also thought that the transition from explore to explain and the extend and elaborate questions all had the students reflect on their learning. While there were student comments on the Evaluate Your Learning survey that one student liked they could write out their thoughts and that one student commented on the depth of these activities did indicate some reflection taking place, I could have done more to help
students reflect as part of the discussion forum. Once again, the Tuesday, Wednesday, Thursday format may have been rushed and limited students' ability to reflect on their learning.

We both rated the assessment parts of the activities as low. The peer reviewer was not clear that the conceptual test and the survey was designed to assess student learning and suggested that I could make the assessment part more explicit in future activities. In addition, we both rated the activity low on the role of assessments. We both noted that the assessments were not adjusted based on any ideas that developed during the inquiry activities. According to the EQUIP instrument, effective assessment should involve more interaction with students, challenging claims by students, and do more to encourage openness and curiosity. Once again, had I been more present on the discussion forums and structured the discussion forums, I could have had more interactions and gently challenged their claims and encouraged them to explore connections to their everyday life.

In the final category of curriculum factors, we both rated the learner centrality as high. I made the comment that to improve learner centrality, I could have students complete a follow-up activity where they designed and completed their own experiment using a simulation software program and report their observations, results, and conclusions back to the class. While we both thought there was a high relationship between content and investigation, the external researcher noted that for some students there appears to be a lack of understanding between activity and being able to discuss topic content in discussion forum posts. This comment from the reviewer also aligns with the student comments about the dislike of the discussion forum posts and the comment on
the EQUIP instrument regarding questioning complexity. Again, a method to improve collaboration and discussion in the forum posts will be presented as a next step in chapter 5. The final section of the EQUIP instrument was the organization and recording of information. My rating of the activity was much lower than that of the peer reviewer. My observation and comment was that the students were answering multiple choice questions as part of the inquiry activity and that I gave students more flexibility in how they recorded and reported in the elaborate or extend section. A future study could focus on an inquiry activity that helps students increase skills in organizing, recording, and reporting data. In addition, creative methods for students reporting in the elaborate and extend sections could be used.

In summary, the EQUIP instrument reveals three areas of improvement in how I structured inquiry activity. The first area of improvement relates to more interaction in the discussion forum. As evidenced by the RTOP instrument and my inquiry journal, the forum posts format could be better structured to allow me to offer more feedback to students. The second area of improvement is the quality and structure of the forum posts. The low satisfaction of students with the forum posts, the observations as part of the EQUIP instrument, and comments as part of this instrument reveal that I could improve on the way I teach students how to structure their forum posts and responses. The final area of improvement is adjusting some of the elaborate and extend activities to better match the initial engage questions and adjusting the evaluation and assessment questions to better align with the questions developed during the activities.

This chapter presented and summarized the major findings of this action research dissertation. While student learning did occur based on the discussion forum posts, the
conceptual test, and the survey question about gas pressure, there were a few consistent misunderstandings and gaps in the students’ knowledge. Without a pre-test or a more formal method of assessing initial student knowledge, I have no information about gains of knowledge in different student groups. The overall positive ratings and comments, especially about the visual and hands-on nature of the activities, from students about the activity indicate that students have a positive attitude towards these activities. The comments and suggestions for change do indicate some shortcomings and weaknesses in the activity and my implementation of the activity that were also reflected in my reflection journal and the RTOP and EQUIP instruments. All of these indicate a need to give more effective feedback as part of the forums, to give better structure and guidance to the forums, and to adjust class activities based on the forum posts and questions raised during the activity. Chapter 5 proposes methods and next steps to supplement areas for growth. Chapter 5 also proposes methods to integrate core ideas and disciplinary concepts as suggested by the ACS and NRC. Finally, Chapter 5 recommends methods of improving these activities to better meet the needs of diverse learners.
### Table 4.1 Implementation Overview

<table>
<thead>
<tr>
<th>Prior to use of 5E Inquiry Activities</th>
<th>I completed pre-inquiry journal entries and reflections</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Week 1</strong></td>
<td><strong>Monday to Tuesday:</strong> Students completed &quot;States of Matter&quot; answers to engage, explore, explain, and elaborate-extend questions to discussion forum. <strong>Wednesday:</strong> Students posted responses to other students about similarities, and differences in original discussion forum post. <strong>Thursday:</strong> Students completed an evaluate response forum post.</td>
</tr>
<tr>
<td><strong>During Weekend</strong></td>
<td>I completed first part of post-inquiry journal reflection questions. I coded and analyze student forum posts for week 1.</td>
</tr>
<tr>
<td><strong>Week 2</strong></td>
<td><strong>Monday to Tuesday:</strong> Students completed &quot;Gas Laws&quot; activity and posted answers to engage, explore, explain, and elaborate-extend questions to discussion forum. <strong>Wednesday:</strong> Students posted responses to other students about similarities, and differences in original discussion forum post. <strong>Thursday:</strong> Students completed an evaluate response forum post. Students completed &quot;Particulate Nature of Matter&quot; concept test. Students completed &quot;Evaluate Your Learning&quot; overall survey of attitudes.</td>
</tr>
<tr>
<td><strong>After use of 5E Inquiry Activities</strong></td>
<td>I completed the second set of post-inquiry journal entries. Peer Reviewer and I completed RTOP and EQUIP Instrument s. I coded and analyzed forum posts for Week 2.</td>
</tr>
</tbody>
</table>
Table 4.2 – Summary of Forum Posts for States of Matter Activities

<table>
<thead>
<tr>
<th>Component of Forum Post</th>
<th>Student Responses</th>
<th>Instructor Observations and Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engage</td>
<td>Definitions of states of matter, relative densities, attractions between particles.</td>
<td>Most students had accurate prior knowledge about simple properties of states of matter.</td>
</tr>
<tr>
<td>Explore</td>
<td>Students had these questions correct due to ability to check work.</td>
<td>None.</td>
</tr>
<tr>
<td>Explain</td>
<td>All answers were correct.</td>
<td>None.</td>
</tr>
<tr>
<td>Elaborate/Extend</td>
<td>Twelve out of thirteen students were able to correctly explain their chosen question. Several students chose more than one question. One student asked independent question.</td>
<td>One student directly stated a common misconception about relative sizes of particles.</td>
</tr>
<tr>
<td>Evaluate</td>
<td>Eight out of thirteen students felt they had learned the content.</td>
<td>Of the five students who did not feel like they had learned anything, one noted that it was a good refresher, one noted more curiosity about relationships, and one noted more awareness of everyday applications.</td>
</tr>
</tbody>
</table>
Table 4.3 – Summary of Forum Posts for Gas Law Activity

<table>
<thead>
<tr>
<th>Component of Forum Post</th>
<th>Student Responses</th>
<th>Instructor Observations and Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engage</td>
<td>Some students related definitions to previous &quot;States of Matter&quot; activity. One student mentioned compressed gases, one mentioned aerosol spray, and one mentioned pressure on a wound.</td>
<td>Most students were able to offer a simple definition of gas pressure.</td>
</tr>
<tr>
<td>Explore</td>
<td>Student responses were overall correct.</td>
<td>Students had ability to check answers with a self-check feature in the simulations.</td>
</tr>
<tr>
<td>Explain</td>
<td>Student responses were overall correct.</td>
<td>Students had ability to check answers with a self-check feature in the simulations.</td>
</tr>
<tr>
<td>Elaborate/Extend</td>
<td>Most students chose to explore relationships between pressure and volume or volume and temperature.</td>
<td>Of students that chose to explore pressure and volume, several students stated the relationship backwards or did not state relationship correctly.</td>
</tr>
<tr>
<td>Evaluate</td>
<td>Twelve out of thirteen students stated they felt like they had learned more about gases.</td>
<td>When asked to define pressure, students did not take into account the volume of the container.</td>
</tr>
<tr>
<td>Concept</td>
<td>Number of Students</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Students who correctly identified relationship between temperature and pressure.</td>
<td>Twelve, ten of which were able to correctly explain the relationship.</td>
<td></td>
</tr>
<tr>
<td>Students who did not correctly identify relationship between temperature and pressure.</td>
<td>One, with no explanation</td>
<td></td>
</tr>
<tr>
<td>Students who correctly identified relationship between pressure and volume.</td>
<td>Five, three of which were able to correctly explain the relationship.</td>
<td></td>
</tr>
<tr>
<td>Students who did not correctly identify relationship between pressure and volume.</td>
<td>Eight, six of which did correctly identify that a larger volume could contain more particles.</td>
<td></td>
</tr>
</tbody>
</table>
Table 4.5 Summary of Student Perceptions of Inquiry Method After Completion of Both Inquiry Activities

<table>
<thead>
<tr>
<th>Question</th>
<th>Number of students that responded 1</th>
<th>Number of students that responded 2</th>
<th>Number of students that responded 3</th>
<th>Number of students that responded 4</th>
<th>Number of students that responded 5</th>
<th>Average Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 1</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>3.7</td>
</tr>
<tr>
<td>Question 2</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>7</td>
<td>1</td>
<td>3.7</td>
</tr>
<tr>
<td>Question 3</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>3.5</td>
</tr>
<tr>
<td>Question 4</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>3.5</td>
</tr>
</tbody>
</table>
### Table 4.6 – Student Survey Ratings Disaggregated by Student Group

<table>
<thead>
<tr>
<th>Student Group</th>
<th>Average Rank for Question 1</th>
<th>Average Rank for Question 2</th>
<th>Average Rank for Question 3</th>
<th>Average Rank for Question 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>3.6</td>
<td>3.8</td>
<td>3.5</td>
<td>3.4</td>
</tr>
<tr>
<td>Male</td>
<td>3.8</td>
<td>3.6</td>
<td>3.6</td>
<td>3.8</td>
</tr>
<tr>
<td>White</td>
<td>4.0</td>
<td>3.8</td>
<td>3.8</td>
<td>3.6</td>
</tr>
<tr>
<td>Non-white</td>
<td>3.2</td>
<td>3.6</td>
<td>3.4</td>
<td>3.2</td>
</tr>
<tr>
<td>High School</td>
<td>3.5</td>
<td>3.5</td>
<td>3.4</td>
<td>3.2</td>
</tr>
<tr>
<td>Traditional College</td>
<td>4.0</td>
<td>4.0</td>
<td>3.8</td>
<td>4.0</td>
</tr>
<tr>
<td>No Prior Chemistry Course</td>
<td>3.6</td>
<td>3.6</td>
<td>3.4</td>
<td>3.4</td>
</tr>
<tr>
<td>Prior Chemistry Course</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>
CHAPTER 5
NEXT STEPS

In this chapter, the results of the research questions and the data and analysis are reviewed. Recommendations are presented about how to improve the structure of the activities, the instructor interaction, the assessments, and the discussion forums as part of the activities. Recommendations for diverse learners are also provided. Ideas for expanding these activities and using these activities to teach students discipline skills are suggested. Finally, recommendations for future study are discussed.

Review of Research Questions

With regards to research question one, there is ambiguity about the results of the effect of the inquiry activities on student learning. Students did state on discussion forum and in student surveys that they felt like they had learned the content. Students did have similar scores on the Particulate Nature of Matter Test when compared to the initial study (Yezierski & Birk, 2006). However, there were lower scores between different racial & ethnic groups, students with or without a chemistry background, and high school and traditional age college students. While students performed well in identifying relationships between temperature and pressure, they did not do well in identifying the relationships between pressure and volume. Once again, high school students in particular scored low on this question.

In identifying student attitudes towards these activities, the positive comments on discussion forums and the student survey scores indicate that students have positive
attitudes towards online inquiry learning. However, the slightly lower scores when comparing different student groups is disappointing. In addition, the number of comments regarding discussion forums and feedback offer key ideas for improvement for next steps.

In research question two, the strengths of my use of inquiry are having students making initial connections as part of the engage step and in finding activities that were challenging, hands-on, and reflective. The weaknesses of my use of inquiry are lack of interaction in discussion forums and lack of adjustment of activities to align observations developed during the inquiry activities.

**Improvement in Structure of Activities and Instructor Feedback**

Several student comments related to the timing and length of the activities. My own self-reflection journal and RTOP and EQUIP instrument also indicate at the Tuesday, Wednesday, and Thursday format was not adequate for me to give feedback to students. One suggestion for improvement would be to change these to a Monday, Wednesday, and Friday format. Students would be directed to complete the engage, explore, and explain steps and complete the inquiry simulations on a Saturday, Sunday, or Monday and directed to post their results to the discussion forum by Monday evening. On Tuesday morning, I would read the forum posts and offer feedback to students, either individually or in small groups. I would modify the extend / elaborate questions and activities based on feedback received on discussion forums. Students would then have Tuesday and Wednesday to complete the extend / elaborate questions. Students would post their extend / elaborate answers on Wednesday evening. On Thursday morning, I
would read posts and offer feedback to students as needed. I would also develop and deploy evaluate questions and activities for students to complete by Friday evening.

While many students that complete online courses expect content to be available for them to complete ahead of time, I would have to be explicit in my instruction of how completion of the activity would take place over several days and students could not work ahead. Because several students made comments about the length of the activities, I would also be more direct about the time commitment needed so that students could plan ahead to complete the activities. Improvement of spacing out due dates would give students more time to reflect on the activity, both individually and in groups in the discussion forum, leading to more increased cognitive and social presence in the online course. Spacing out due dates would also allow me more time for providing feedback, thus improving the teaching and social presence in the course. Table 5.1 displays the modified format to allow for more student and instructor feedback and reflection.

Another idea relates to the structure of the extend/elaborate questions. One concept I noticed in reviewing my reflections and definition of inquiry was that the elaborate/extend question for the Gas Laws activity was set up backwards. I asked students to find the definition and explanation first, then find the everyday example. To better align with definitions of inquiry, I could have asked students to research how breathing works and examine the section of the inquiry simulation that relates pressure and volume more closely. I then would have students summarize the relationship and then research the relevant gas law.

I would also read forum posts about engage, explore, and explain observations before deciding and developing extend/elaborate questions and activities. One
recommendation from the EQUIP instrument is more interactive assessments. As an example, in the engage step for the Gas Laws activity, one student related gas pressure to compressed gases and another related gas pressure to a can of cooking spray. I could have changed the extend elaborate questions to better relate to these everyday observations and used these everyday observations to better explain the concept of gas pressure.

Finally, I gave very proscribed extend/elaborate activities. One area of improvement would be for me to offer a starting point for students but also make students aware that they were encouraged to find a different application to elaborate upon. For example, in the states of matter activity, several students mentioned engage ideas related to sublimation and printing of t-shirts. I could have encouraged those students to elaborate on how that process relates to the phase changes learned as part of the States of Matter activity.

The students also made their extend/elaborate posts as a simple discussion forum post. While as part of the RTOP instrument, the peer reviewer rated the fact that students were not confused by multiple forms of communication as high, I rated that as a low. I could have offered students the ability to post short videos of themselves explaining their extend/elaborate question to appeal to students who were more comfortable with auditory and visual communications. In my reflection journal, I noted how I felt that science was all around us. When diverse students see science laboratories and demonstrations performed by a White male in a lab coat, they may feel excluded or that science is not relevant to them (Lee & Buxton, 2011). Having diverse students performing a demonstration using household materials would assist students in recognizing how science is all around them and that anyone can be a scientist.
Recommendations for Improvement of Assessments

One design flaw that I did not recognize until I began to analyze data from completed activities was the lack of an official pre-test. A pre-test would have allowed me to better gauge gains in student learning as part of the States of Matter and Gas Laws activities. While the engage forum posts can be seen as a type of pre-test, the three to four general statements posted by students were not sufficient to judge the depth of their knowledge of the subject matter. However, care would need to be taken so that students understand that low score on a pre-test would not count against them, but a low score would only be used to help improve their learning. Based on results of a pre-test, I could then modify the explore and explain questions as part of the activity to build on student strengths and to give students more reinforcement in areas where they were weak.

Final assessments as part of the evaluate step could be improved in several ways. I noted in the RTOP and EQUIP instruments that the assessments were mainly multiple-choice questions. The assessments could be expanded to include a question where students drew a picture of what they would predict to happen and then upload their picture as part of their assessment, concept test. Another idea is to provide pictures of possible results, have students select the appropriate picture, and explain why they chose their picture. The main textbook for this course involves several “Conceptual Connections” review questions in the picture and explain format (Tro, 2018). While the textbook provides answers so that students can check their results, these questions could be modified for an assessment test. A picture question or a short answer question would allow for me to obtain more information about the depth of student knowledge. These types of questions would also appeal to students who were more comfortable expressing
themselves visually, pictorially, or in writing. Inclusion of multiple forms of assessment may improve both the scores and the overall attitudes of diverse learners in CHM 151.

**Improvement of Discussion Forums**

I have noted previously that structuring the discussion forums in a Monday, Wednesday, and Friday format would improve the type and depth of feedback that I could provide to students. As part of student surveys, several students noted that they did not get a lot out of the discussion forums. As part of the EQUIP instrument, the peer reviewer noticed that there seemed to be a disconnect between the student activity and the posts on the forum. These observations and comments indicate a need to strengthen how students complete discussion forum posts. There are two main ideas of how to structure discussion forums. One method is the claim-evidence-reasoning (CER) framework and the other is the Paul-Elder critical thinking framework.

One recent development in science teaching is the claim-evidence-reasoning (CER) framework (Sampson, et al., 2015). As the name suggests, students are directed to complete an inquiry activity and record observations and data. Students are then directed to make a claim about the relationships between observations and data. Students list the evidence that support their claim. Finally, the reasoning step has the students explain their reasoning pattern or has students make appropriate connections. The focused structure of this argument framework could improve the quality of the discussion forums and promote students to make better connections between observations in different parts of the activity. As the instructor, I would either need to model and give several examples of well-structured and not well-structured CER arguments. I would need to provide additional instruction for students of how to complete a CER argument. Improvement in
this area would also assist students in completing discussion forums in other online
courses and improve how students interpreted and explained observations in other
science classes. An increased understanding of structuring scientific arguments would
also be helpful for students without a previous science class and helpful for students who
are transitioning between high school and college courses.

A second method for structuring arguments and discussion forum posts is the
Paul-Elder Critical Thinking Model’s elements of thought and intellectual standards
(Elder & Paul, 2010). In the elements of though, students are encouraged to deeply
examine their points of view, purpose, question being asked, information needing to be
collected, and the appropriate interpretations that should be made. In particular, students
would find considering the question to be answered and information needed helpful in
approaching an inquiry problem and making their initial posts about engaging, exploring,
and explaining initial observations. Elder and Paul’s Intellectual Standards are a set of
guided questions as students work in groups. These standards would be used as starting
points for students’ response posts to each other. These standards have students question
each other’s clarity, accuracy, precision, relevance, logic, breath, depth, and fairness. In
particular, questions related to clarity, accuracy, precision, and logic would be useful in
students examining their own and other students’ arguments.

I would need to provide additional training and examples for students for using
this model in replying to each other in the discussion forums. Because some students may
not feel comfortable in disagreeing with other students or feel uncomfortable receiving
disagreements, I would provide reassurance that disagreement is acceptable and examples
of how to properly disagree with other students. I would also carefully monitor discussion
forums to ensure disagreements were being completed respectfully. Explanations of this model would assist students in completing discussion forum problems in other classes and in being able to evaluate their own and other students’ arguments. Improved methods for discussion forum activities would allow for increased cognitive presence and social presence in the course. The cognitive presence would be improved in that students would be able to make clearer connections between observations and chemistry content. The social presence would be improved because students would have a better framework to interact with each other on the discussion forums.

**Improvements for Diverse Students**

As indicated in the improvements for the activities and instructor feedback, one improvement that could be made is in the elaborate/extend step. While I believe, based on the results of the forum posts and RTOP and EQUIP instruments that I did a good job having students make the initial or engage connections to their everyday lives, I could have done a better job with connections in the elaborate/extend questions. As stated in chapter 1, CRP encourages students to make connections to their everyday lives and recognizes the importance of those connections. One idea proposed earlier in this chapter was for students to find their own elaborate/extend question they would encounter in their daily life. This question might also take on the form of a demonstration or activity with easy to obtain household substances. Rather than post results to a discussion forum, students would have the option to post a video of them explaining their questions or performing their demonstration. The video format would appeal to students who felt more comfortable with auditory and visual explanations. Everyday examples and demonstrations would assist students in seeing the relevance of science to their everyday
life, that those students could be scientists, and dispel the myth of the crazy, white male scientist in the lab (Lee & Buxton, 2010).

Improvement in the extend/elaborate step and on the discussion forum would also be beneficial for English Language Learners. English Language Learners (ELL) have improved outcomes and improved language acquisition when given a context, such as scientific inquiry, for learning the language. Grounding language learning with scientific skills in the inquiry activities, with corresponding visual and hands-on components and applications to everyday life, may improve both attitudes and outcomes for ELL students. ELL students also may feel more comfortable expressing themselves in an auditory, visual, or kinetic format. Changing the extend/elaborate response in the discussion forum to allow for multiple forms of response may also improve attitudes and outcomes for ELL students. Finally, students also have gains in improvement in language learning when given the context and structure, such as CER or Paul-Elder Critical Thinking Model, for developing arguments (Lee & Buxton, 2011). Teaching, giving examples, and reinforcing these argument structures for discussion forum responses would benefit all students in General Chemistry 1.

As indicated in the RTOP and EQUIP instrument results and in a previous section on improving assessment, I felt that the simple multiple-choice questions were not sufficient for authentic assessment of student learning. One idea to improve outcomes for diverse learners would be to use multiple forms of assessment, such as visual representation or explaining reasoning in a short answer format. However, I would need to ensure that sufficient time was given for EEL students to compose and proof-read an
essay response. I would not want EEL students to feel they were rushed in having to compose and edit their responses and reasoning.

**Expansion of Activities to Teach Scientific Practices**

One of the main goals of this action research dissertation was for me to increase my understanding and ability in inquiry teaching online. I chose several simple and straightforward activities for student use. The NRC (2012) list recommended Scientific Practices that should be included in all levels and all types of science courses. While these practices are intended to be used in a K–12 setting, these practices would also be relevant to CHM 151. CHM 151 is taken by many dual enrolled high school students to obtain a high school chemistry or physical science credit. CHM 151 is also taken by students who have not had a previous science course. Those groups of students would need extra practice and reinforcement to assist them in succeeding in science classes. The recommended scientific practices from the NRC include asking questions, development and use of models and explanations, planning and performing investigations, analysis and interpretation of data, constructing arguments based on data and observations, and scientific communication.

One idea for future study would be to develop or modify inquiry activities that emphasize these scientific practices. As an example, the Gas Laws are widely recognized (Uthe, 2002) as a method of teaching scientific practices. The Gas Laws activity used in this dissertation could be modified for students to use the simulation to explore mathematical relationships between the various properties of gases. Students would be directed to prepare a graph, interpret their graph, and identify important mathematical relationships from their graph. Both of the States of Matter and Gas Laws activities could
be modified so that the portion of the activity where students construct models and explanations were emphasized. Students would be directed to post their models and explanations, with the guided CER or Paul-Elder framework, to a discussion forum. Students may also post their explanation as a constructed still image or a video. Students would then use the Paul-Elder framework to engage in arguments about each other's models and explanations and evaluate each other's evidence and reasoning.

While the Concord Consortium modeling activities were used as part of this action research dissertation, there are other online sources for activities. Different online simulations and inquiry activities could be investigated for better alignment with CHM 151 content and the NRC's scientific practices. Observations and comments that were part of the RTOP and EQUIP instruments indicated that the activities from the Concord Consortium were very proscribed and only had one or two methods of investigation. Other simulation and online activities could be used that were more open ended for student exploration and investigation. More openness in investigation would allow for deeper inquiry experiences, more opportunities for students to plan and perform experiments online, and for students to evaluate arguments. If the Scientific Practices were chosen as an emphasis for CHM 151, then inquiry activities could be found or developed that emphasized and focused on each individual practice. The current textbook for CHM 151 (Tro, 2018) has ten chapters that are used in CHM 151. An inquiry simulation activity could also be found or developed that emphasizes the main content area from each chapter.
Recommendations for Future Studies

The inquiry activities in this dissertation were implemented over two weeks in a CHM 151 course. One possible future study is to use inquiry activities through the entire semester and track students learning outcomes and attitudes and my understanding and reflections about the nature of inquiry teaching over the span of an entire semester. Many studies in the literature review examined overall performance of students during an entire semester (Farrell, Moog, & Spencer, 1999; Lewis & Lewis, 2005; Conway, 2014). Expanding research over an entire semester would allow for comparison to these prior studies. These prior studies also tracked student grades at the end of a semester; final student grades could also be studied for a course that used online inquiry over the entire semester.

The small sample size in this study provided limited information about student diversity and demographics. This study could also be performed in a semester when several sections of online CHM 151 were offered. There would be a larger sample size and possibly a greater diversity of student types. Completion of this study over several courses by increasing the sample size would provide more information about learning patterns of diverse learners to address the enduring problem of diversifying the STEM fields which is highly linked to student success in chemistry and other science and math courses (NRC, 2012; NSF, 2019).

Final Conclusions

Once the COVID-19 pandemic ends and I transition back to in-person teaching, how will I use the knowledge gained in this dissertation to improve my own practice of teaching? From this study, I find that I am able to modify and adapt existing inquiry
activities to be more structured to the 5E model and to be more relevant to students. Regardless if I am using traditional lecture or inquiry methods for teaching, I am aware of using everyday examples in the classroom and encouraging students to find, develop, and report on their own everyday examples and analogies. I have also discovered that good inquiry teaching involves the discovery of the concept (explore) before invention of explanation (explain). Regardless if I am using traditional lecture or inquiry methods, I have a greater awareness of how to frame lessons. In the opening of a lesson, I can ask a question, pose a problem, perform a demonstration, or give an everyday example first. I can then either have students develop the explanation in inquiry or I can formally state the explanation in lecture.

I am also more aware of the importance of questioning back and forth between myself and students. Both the RTOP and EQUIP instruments indicate that I can do more in interactions with students. Regardless if I am teaching by lecture or inquiry methods, I can do better with asking questions of my students, having them question me about my assumptions, and having students confidently present results. I can still use the CER and Paul-Elder models to teach students how to present and respond to scientific claims. While I will go back to traditional, in-person teaching, I will not go back to the way I was teaching. I will use more inquiry-based lessons in my classroom. I will be on the lookout for, and I will encourage my students to be more aware of, examples and analogies of science in their everyday lives. Finally, I will integrate more structured discussions and more lessons how to structure scientific arguments into my classroom.

While some curriculum specialists criticize inquiry as only being a method of instruction and not an agent for social change (Windschitl, 2011), I view inquiry as an
important tool for students being able to identify areas of social change. As an example, Travis (2013) states that one of her goals in using inquiry is that she wants her students to be more scientifically literate and determine how scientific concepts relate to their everyday lives. As an example, she states that students are able to have more informed conversations with their physicians about medical treatment. Brown (2017) cites several studies where the use of inquiry made students more aware of the environmental issues in their neighborhoods and how those issues impacted their lives. Brown also reported that students were able to find relationships between social class, poverty, and environmental issues through scientific inquiry.

When I use more inquiry-based and CRP practices in my teaching, students can become more inquisitive in their own lives. Students can start to determine the connections between science, their daily lives, and the issues they encounter. Students would be empowered to have significant conversations with physicians, politicians, and scientists about environmental and health issues. My desire is for my students to have the same passion for science that I do, to be able to see science everywhere, and to be able to use their scientific knowledge and inquiry tools from my class to accomplish change for themselves, their families, and their communities.
### Table 5.1 – Modifications to Schedule of Activity

<table>
<thead>
<tr>
<th>Days</th>
<th>Saturday to Monday</th>
<th>Tuesday to Wednesday</th>
<th>Thursday to Friday</th>
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<tbody>
<tr>
<td>Items to</td>
<td>The students complete engage, explore, and explain questions and post answers to</td>
<td>The instructor reads students' posts and designs elaborate/extend questions based on</td>
<td>The instructor reads students' posts and offers any final comments or reflection</td>
</tr>
<tr>
<td>complete</td>
<td>discussion forum.</td>
<td>students' posts. Students complete elaborate/extend questions and activities and post</td>
<td>questions. Students complete a evaluate your learning final reflection post. If</td>
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<td></td>
<td></td>
<td>results to discussion forum.</td>
<td>necessary, students complete test to evaluate understanding.</td>
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REFERENCES


APPENDIX A

DIRECTIONS FOR STATES OF MATTER 5E ACTIVITY

Engage with the content and concepts
Write down 3 – 4 ideas or concepts you know already about solids, liquids, and gases. These could be facts from previous science classes, how you think they are similar or different, or how you encounter them in your daily life.

Explore the relationships
Go to the Concord Consortium Website: http://mw.concord.org/nextgen/
Select "States of Matter" and complete the activities
1. Describe the motion of the atoms in the gas.
2. The image shows a seemingly empty glass.
   Why can't you store a fixed amount of gas in an open container like a glass?
3. Describe the movement of the atoms in a liquid. How do they move relative to each other?
4. The image shows a glass, half-filled with water.
   Why does the liquid change shape to fill the bottom of the glass?
5. Describe the movement and arrangement of atoms in a solid.
6. The image shows a crystal of rock salt (halite).
   Why does the solid have a specific shape?
   Why does it not change shape?

Explain the relationships
7. How will you be able to tell whether the material is a solid, liquid or gas?
   (Hint: Think about how atoms move relative to each other in the different states of matter.)
8. Which attraction level would allow a material to be a gas at a very low temperature?
9. What is the role of charge on a material’s state of matter at a medium temperature?

10. Explain your answer to number 10.

11. Go back and examine several of the simulations. What appears to happen to the volume of a solid when it melts? What appears to happen to the volume of a substance as the temperature increases?

**Elaborate on and expand on your learning.**
Choose one of the following four questions to answer about the properties of solids, liquids, and gases. These explanations should be 3 – 4 sentences and in your own words.

1. How and why does the "lava" in a Lava Lamp float and sink?

2. Why can you run hot water over a stuck metal jar lid to loosen the lid?

3. Why do glass windows seem to rattle in the winter when wind blows?

4. Examine the following demonstration of a metal ring and sphere. Explain how and why the demo works.
https://youtu.be/QNoE5IoRheQ

Post your answers to the Engage, Explore, Explain, and Elaborate/Expand questions to the discussion forum by TUESDAY at 11:55 PM. Respond to at least TWO classmates by WEDNESDAY at 11:55 PM. Your responses should focus on areas of agreement between classmates, areas of disagreements, and any new insights that you learned by reading your classmates’ work.
APPENDIX B

DIRECTIONS FOR GAS LAWS AND WEATHER BALLOONS

ACTIVITY

Engage with the content and concepts
Write down 3 – 4 ideas or concepts you know already about the properties of gases. These could be facts from previous science classes, a summary of the previous inquiry activity, or how you encounter them in your daily life.

Write down what you think the word "pressure" means:

Explore the Relationships.
Go to the following website: http://mw.concord.org/nextgen/
Complete the Gas Laws and Weather Balloons Tutorials.

1. If the gas molecules outside the balloon collide into the balloon surface more than the gas molecules inside the balloon collide into the balloon surface, what will happen?

2. If the gas molecules outside the balloon collide into the balloon surface more than the gas molecules inside the balloon collide into the balloon surface, what will happen?

3. How could you increase the number of collisions on the inner surface of the balloon without changing the number of atoms?

4. When the temperature increases, what happens to the pressure the molecules exert on the balloon?

We will revisit question 5 later!
5. What happens when the number of molecules is decreased?

6. When you increase the volume of the balloon, what happens to the pressure the molecules exert on its skin?

**Explain the Relationships**

7. Why does the balloon expand when the gas is heated?

8. Why does the weather balloon burst at high altitude?

**Elaborate and Expand on Your Learning**

Pick ONE of the following questions to answer about the properties of gases.

1. What is Boyle's Law? Explain Boyle's Law on a molecular level using what you learned in the tutorials. How does breathing relate to Boyle's Law?

2. What is Charles's Law? Explain Charles's Law on a molecular level, using this tutorial or the previous tutorial. How might you encounter Charles's Law in your everyday life?

3. What is Gay-Lussac's Law? Explain Gay-Lussac's Law on a molecular level, using this tutorial or the previous tutorial. How does Gay-Lussac's law relate to an aerosol can placed in a fire?

4. View the following demonstration about crushing a can using ice-water. Explain, using what you know about gases, why the can is crushed.
   https://youtu.be/atsgIvOUFhA
Post your answers to the Engage, Explore, Explain, and Elaborate / Expand questions to the discussion forum by TUESDAY AT 11:55 PM.

Respond to at least TWO classmates by WEDNESDAY at 11:55 PM. Your responses should focus on areas of agreement between classmates, areas of disagreements, and any new insights that you learned by reading your classmates’ work.
APPENDIX C

PARTICLE NATURE OF MATTER TEST QUESTIONS

1. Consider three samples of water in three phases. The first is solid water (ice) at 0°C, the second is liquid water at 24°C, and the third is gaseous water at 100°C. The water molecules in the liquid phase __________ the water molecules in the gaseous phase.
   A. move faster than
   B. move slower than
   C. move at the same speed as
   D. move more randomly than

2. Which of the following processes will make water molecules larger?
   A. freezing
   B. melting
   C. condensation
   D. none of the above

3. A water molecule in the gas phase is ______ a water molecule in the solid phase.
   A. smaller than
   B. lighter than
   C. larger than
   D. the same weight as

4. When water is vaporized, it is changed to
   A. hydrogen and oxygen
   B. air, hydrogen, and oxygen
   C. gaseous water
   D. air

5. A pot of water is placed on a hot stove. Small bubbles begin to appear at the bottom of the pot. The bubbles rise to the surface of the water and seem to pop or disappear. What are the bubbles made of?
   A. heat
   B. air
   C. gaseous oxygen and hydrogen
   D. gaseous water
6. A pot of water on a hot stove begins to boil rapidly. A glass lid is placed on the pot and water droplets begin forming on the inside of the lid. What happened?
A. Steam cools and water molecules moved closer together.
B. Water from outside leaked into the pot.
C. Hydrogen and oxygen combined to form water.
D. Steam combined with the air to wet the inside of the lid.

7. Consider three samples of water in three phases. The first is solid water (ice) at 0°C, the second is liquid water at 24°C, and the third is gaseous water at 100°C. The water molecules in the liquid phase _________ the water molecules in the solid phase.
A. move faster than
B. move slower than
C. move at the same speed as
D. move less randomly than

8. A wet dinner plate is left on the counter after it has been washed. After awhile it is dry. What happened to the water that didn’t drip onto the counter?
A. It just dries up and no longer exists as anything.
B. It goes into the air as molecules of water.
C. It goes into the plate.
D. It changes to oxygen and hydrogen in the air.

9. Which of the following processes does NOT require heat energy?
A. evaporating water
B. melting ice
C. boiling water
D. condensing water

10. When water molecules in the gas phase are heated, the molecules themselves
A. expand.
B. move faster.
C. become less massive.
D. Both A and B.

11. When water at 25°C is heated and changes to a gas at 110°C, the water molecules
A. become more organized.
B. move farther apart.
C. stop moving.
D. move more slowly.
12. A water molecule in the liquid phase is _______ a water molecule in the solid phase.
   A. smaller than
   B. lighter than
   C. larger than
   D. the same weight as

13. When water at 24°C is cooled to 0°C and freezes, the water molecules
   A. become less organized.
   B. move much faster.
   C. stop moving.
   D. move much more slowly.
APPENDIX D

EVALUATE YOUR LEARNING STUDENT SURVEY

On a scale of 1 - 5, with 1 being strongly dislike and 5 being strongly like, rate how well you liked these activities. If needed, explain your answer in 2-3 sentences.

On a scale of 1 - 5, with 1 being no learning and 5 being a large amount of learning, rank how well you believe you learned from these activities. If needed, explain your answer in 2-3 sentences.

On a scale of 1 - 5, with 1 being never again and 5 being every assignment / activity, how often would you want to learn chemistry content by these interactive simulations? If needed, explain your answer in 2-3 sentences.

On a scale of 1 - 5, with 1 being no confidence and 5 being high confidence, rank how well you believe you can learn chemistry by using these simulation activities. If needed, explain your answer in 2-3 sentences.

What is one thing you liked about these activities? Please respond with 3-4 sentences.

What is one thing you would change about these activities? Please respond with 3-4 sentences.
A quick check of your learning:

You have four samples of oxygen gas. Each sample contains the same amount of oxygen. Which sample would have the highest pressure?

A) 1.0 L of oxygen at 25 °C  
B) 5.0 L of oxygen at 25 °C  
C) 1.0 L of oxygen at 50 °C  
D) 5.0 L of oxygen at 50 °C.

Explain your answer in 2-4 sentences.

Help me understand your background:

1. What is your gender?

2. What is your race/ethnicity?

3. What is your age?

4. Are you a dual-enrolled / career and college promise student?

5. Have you completed a high school chemistry class within 5 years of enrolling in this course?
APPENDIX E

SELF REFLECTION JOURNAL QUESTIONS

Before inquiry activity is used in online chemistry courses

1. I will describe my science background.
   a. The methods used to teach me science in secondary, undergraduate, and graduate levels.
   b. Previous laboratory and research experience.
   c. How I perceive science as part of my daily life.

2. How do I think students learn science?

3. How do I know when someone has learned something?

4. What are some of my strengths as an instructor?

5. What are some of my weaknesses as an instructor?

6. What is an effective teaching lesson I have used in a traditional lecture class?

7. What is my definition of inquiry teaching?

8. How did I use inquiry teaching in a traditional lecture classroom?
   a. As a teacher, what did I do in an inquiry lesson in a traditional classroom?
   b. What are my students doing in an inquiry lesson in a traditional classroom?
   c. What books or resources are being used in an inquiry lesson?
   d. How is the science content taught during an inquiry lesson?

9. Do I believe that inquiry teaching a good way to teach science content? Why or why not?
10. Are their times when inquiry teaching is not useful? Why or why not?

11. What constraints or hesitancies do I have about inquiry teaching online?

12. How do I use reflection in designing instruction and inquiry activities?

After the inquiry lesson is used in the online courses – States of Matter

1. What is a meaningful experience that occurred to me during the inquiry lesson?

2. What are some meaningful experiences of my students that I observed during the lesson?

3. Have my ideas or definitions about inquiry changed during the lesson?

4. How did I use inquiry teaching in the online classroom?
   a. Did my role as a teacher change in the online classroom?
   b. Did the actions of my students change in the online classroom?
   c. Did I observe books or other resources being used in the online classroom?

5. Did my constraints or hesitancies about online teaching influence my inquiry lesson? If so, how?

6. Did I use reflection during the inquiry lesson? If so, how?

After the inquiry lesson is used in the online course - Gases

1. What is a meaningful experience that occurred to me during the inquiry lesson?

2. What are some meaningful experiences of my students that I observed during the lesson?

7. Have my ideas or definitions about inquiry changed during the lesson?

8. How did I use inquiry teaching in the online classroom?
   a. Did my role as a teacher change in the online classroom?
   b. Did the actions of my students change in the online classroom?
c. Did I observe books or other resources being used in the online classroom?

9. Did my constraints or hesitancies about online teaching influence my inquiry lesson? If so, how?

10. Did I use reflection during the inquiry lesson? If so, how?