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A Phenomenological Study of Science Teachers' Lived Experience: Pedagogical Judgment During the COVID-19 Pandemic

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Abstract

At the beginning of the COVID-19 pandemic, in March of 2020, education in the United States changed dramatically. Science teachers began to look at the implementation of ambitious and equitable science teaching practices differently. Employing the hermeneutic phenomenological framework, the purpose of this study was to investigate the lived experience of science teachers, specifically looking at their pedagogical judgment related to ambitious and equitable science teaching. Semi-structured interviews, artifacts and surveys were used to develop a rich description of the phenomenon. Data analysis of the science teachers' narratives, Qualtrics surveys, and lesson plans illuminated six essential themes common to all the participants: (1) first impressions of the pandemic; (2) confusion of the pandemic; (3) a new normal; (4) technology as aid and hinderance; (5) thoughts on equity; and (6) facilitating ambitious science teaching. Participants expressed that contributing to this study, specifically sharing all their stories about science teaching during the height of the pandemic, was therapeutic. This study is one of the first to investigate the lived experience of the science teacher as they navigate their pedagogical judgment around ambitious and equitable science teaching during the COVID-19 pandemic.

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At the beginning of the COVID-19 pandemic, in March of 2020, education in the United States changed dramatically. Science teachers began to look at the implementation of ambitious and equitable science teaching practices differently. Employing the hermeneutic phenomenological framework, the purpose of this study was to investigate the lived experience of science teachers, specifically looking at their pedagogical judgment related to ambitious and equitable science teaching. Semi-structured interviews, artifacts and surveys were used to develop a rich description of the phenomenon. Data analysis of the science teachers' narratives, Qualtrics surveys, and lesson plans illuminated six essential themes common to all the participants: (1) first impressions of the pandemic; (2) confusion of the pandemic; (3) a new normal; (4) technology as aid and hinderance; (5) thoughts on equity; and (6) facilitating ambitious science teaching. Participants expressed that contributing to this study, specifically sharing all their stories about science teaching during the height of the pandemic, was therapeutic. This study is one of the first to investigate the lived experience of the science teacher as they navigate their pedagogical judgment around ambitious and equitable science teaching during the COVID-19 pandemic.

Keywords: COVID-19 pandemic, ambitious science, equity, pedagogical judgment, hermeneutic phenomenology

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Chapter One: Introduction, Purpose, and Research Questions

Over the past several years our world has been plagued by the COVID-19 pandemic. In education, this has resulted in school shut-downs, remote learning, partial re-openings, mask mandates, COVID-19 testing mandates, COVID-19 vaccination mandates, and more (UNESCO, 2020). These immense changes to the education sector in the United States swiftly disrupted the manner in which teachers conduct class and students engage in learning (An et al., 2021; Reich et al., 2020).

When teachers needed to quickly shift to remote learning at the beginning of the pandemic, secondary science educators adjusted their instruction. How did science teachers navigate the important tenets of the Next Generation Science Standards, especially inquiry and equity? Some of the challenges when planning for remote learning included community building while distanced, facilitating student discussions in an online environment, and developing and implementing inquiry projects.

When schools began to partially reopen with reduced class sizes, mask mandates, and social distancing rules, secondary science educators adjusted their instruction again. How did teachers navigate new pandemic guidelines while providing highly effective science teaching? Some of the challenges included equitable grouping of students while considering masking compliance, social distancing guidelines while moving through the classroom for science experiments and investigations, and facilitating class discussions

while wearing masks. With each COVID-19 variant and increases/decreases in COVID-19 cases, districts and schools responded with changes to classroom instruction. How did these abrupt changes affect secondary science instruction?

Context

The National Survey of Science and Mathematics Education (NSSME+)[1] conducted a pre-pandemic study detailing science, mathematics, and computer science education in the United States (NSSME+, 2018). The NSSME surveyed teachers from all 50 states, with approximately 1,300 schools and 7,000 teachers participating. According to the NSSME+ study, approximately 50% of high-school and 48% of middle-school classrooms included science investigations weekly. Lessons in 11% of middle-school and 12% of high-school classrooms included hands-on and laboratory activities daily (NSSME+, 2018). The data for the next NSSME+ assessment will cover classroom instruction during the height of the pandemic; it will be interesting to view the data and determine if the frequency of hands-on, laboratory activities and science investigations in U.S. classrooms will be comparable to the pre-pandemic frequency.

One of the major contributors to science teachers' instructional focus is the Next Generation Science Standards (NGSS, 2013). The NGSS shifted the focus of science learning to broad scientific conceptual understanding using investigations and student-centered inquiry, rather than rote learning of specific finite science standards. NGSS also included a new section — "equitable learning opportunities" — which was a first for science standards (NGSS, 2013). Equitable learning opportunities (ELOs) emphasize

[1] The plus symbol reflects the NSSME study's emphasis on computer science and engineering in 2018 and beyond.

equity in science education by drawing on students' funds of knowledge and increasing diversity awareness. These NGSS initiatives provide a framework of inquiry and equity for teachers when developing lessons.

The NGSS's emphasis upon investigations and equity aligns with Ambitious Science Teaching (AST), a newer framework in science (Stroupe, 2016). Often referred to as highly effective science teaching, Ambitious Science Teaching practices are rigorous and informed by research (Windschitl et al., 2018). For this study I focus on the scientific inquiry portion of Ambitious Science Teaching. I explain in-depth the AST framework in the definitions section of this chapter.

Before the pandemic, 50% of science teachers in the U.S. engaged students in investigations approximately weekly, according to the NSSME+ survey. How did science teachers navigate the commitments to investigations equitably while conducting class remotely? Did science teachers act on their commitments to providing scientific inquiry in an equitable environment? The NGSS's emphasis upon investigations and equity, coupled with the challenges of providing highly effective science instruction during the pandemic, created a unique situation to research.

Significance of Research

This phenomenological investigation explored science teachers' pedagogical judgment in relation to ambitious science teaching and equity through the many changes in education throughout the COVID-19 pandemic. Understanding the lived experiences of secondary science teachers in the United States during the height of the pandemic provides greater understanding of highly effective science instruction regardless of delivery method (remote, socially distanced, masked, etc.). By illuminating the

pedagogical judgment teachers exercised related to highly effective science instruction and how teachers navigated instruction based on their judgments during the pandemic, this phenomenological study informs many areas within the science education sector. Education researchers, teacher educators, school leaders, and science teachers may use the information gathered from this study to inform curriculum development and highly effective science education practices during highly disruptive circumstances to education in the future.

Purpose Statement

The purpose of this hermeneutic qualitative phenomenological study is to highlight the experiences of secondary science teachers and their pedagogical judgment in relation to highly effective science instruction during the COVID-19 pandemic. By interviewing secondary science teachers in the United States, I describe the phenomenon of teaching secondary science during the height of a pandemic. As a result of this study, educators will better understand how to provide highly effective science instruction during extreme disruptions to the status quo.

Research Questions

1. What does the lived experience of science teachers during the pandemic tell us about pedagogical judgment during the pandemic and pedagogical judgment in general?
2. How do science teachers navigate their pedagogical judgment in relation to ambitious and equitable teaching?

Theoretical Framework

The theoretical framework for this hermeneutic phenomenological study examined the pedagogical judgment science teachers exercise while considering the real-life application of non-ideal theory. In this section, I first define the phenomenology approach that I used in this study. Hermeneutic phenomenology is a philosophical approach that researchers use to understand how people (participants) experience the world. Next, commitments to scientific inquiry, along with equity, shape the pedagogical judgments related to highly effective science instruction. Finally, the continuum between ideal and nonideal theory recognizes the imperfect state in which teachers carry out instruction and strive for improvement.

Hermeneutic Phenomenology

A hermeneutic phenomenological study describes personal experiences through in-depth interviews and conversations to explain the essence of a phenomenon (Guillen, 2019). In hermeneutic phenomenology, it is necessary for the researcher to recognize their biases and experiences that may contribute to their interpretation of the research. A researcher uses a hermeneutic circle, as developed by Martin Heidegger, to aid in the discovery of their assumptions and biases while comparing and contrasting the experiences of the participants within the same phenomenon (Peoples, 2021). To gain an understanding of the whole phenomenon, the researcher analyzes the individual parts of the experience then circles back to the whole phenomenon with new understandings. The hermeneutic circle is a constant practice throughout the research as new data is gathered and analyzed (Peoples, 2021).

As the researcher, I used the hermeneutic circle to make sense of the lived experiences of the participants through my similar exposure as a science teacher during

the COVID-19 pandemic. I journaled to aid in revising my personal biases while developing new understandings and meanings of the lived experiences of a science teacher during the pandemic (Peoples, 2021). Each time I journaled I put my thoughts and ideas of a participant's experience on paper, which allowed me to examine my assumptions and biases. This examination then allowed me space to consider the participant's experience through their context, letting go of my preconceived ideas. Through the examining of my assumptions and biases I hoped to understand the participant's experience more thoroughly through their life context and experience. I chose hermeneutic phenomenology because the method protocol recommends a researcher engage in personal reflection, thus resulting in an enlightened view of a participants' experience. Reflecting on my preconceived ideas to arrive at new understandings of the phenomenon was beneficial for such a highly personal and unsettling event as the COVID-19 pandemic.

Pedagogical Judgment

Pedagogical judgment refers to the choices and responses teachers make in relation to the values in teaching that facilitate and promote students' learning (Sanchez, 2014; Stengel & Casey, 2013). Teachers often use their pedagogical judgment in determining classroom facilitation, especially if the pedagogical judgment involves a value that is important to their individual teaching practice. For example, a teacher values facilitating investigative opportunities for students regularly. This meant that the teacher used their pedagogical judgment to find ways to incorporate science investigations into lessons and teach students the components of science investigations rather than teaching science concepts through other methods. This might mean the teacher spent more class time on

teaching scientific concepts through investigations, thus leading to less class time spent on other science competencies. This teacher's exercise in pedagogical judgment meant the teacher chose science investigations as a priority over other science competencies.

One way to view pedagogical judgment is in three parts: pedagogical action, pedagogical reasoning, and pedagogical responsibility (Horn, 2019). I discuss the intricacies of this tripartite view and provide a hypothetical scenario of pedagogical judgment in more detail in Chapter Two. In the scenario above the teacher had many possible responses in deciding how to teach science concepts, this is referred to as a pedagogical action. Regardless of what they decided, teachers use pedagogical judgment to weigh various factors and select the best course of action for the unique situation and the methods they value.

Another responsibility commonly affecting a science teacher's pedagogical judgment is the desire to connect science to the everyday lives of their students (Smith, 2020). This potentially equitable practice helps students make connections to their lives, thus increasing science understanding. According to the NSSME+ (2018), 99% of high school teachers surveyed held the pedagogical responsibility that it is necessary to connect science to students' everyday lives (NSSME+, 2018). This value then affects the pedagogical actions a teacher makes in the classroom. A teacher might spend extra time connecting a concept to experiences her students have had at the expense of other scientific practices. The pedagogical judgment related to choosing one science practice over another is the thought process I uncovered as I researched teacher's moves and choices during the COVID-19 pandemic.

Ideal and Non-Ideal Theories

Ideal and non-ideal theories provide a continuum of conditions in which education occurs. Ideal theory represents the utopian or idealistic manner in which education takes place (Valentini, 2012). Non-ideal theory recognizes the human element within education (Jaggar, 2017). The idea of non-ideal theory is to work towards a realistic utopia while considering the human element (Jaggar, 2017; Valentini, 2012). Achieving a realistic utopia is a constant work-in-progress (Jaggar, 2017).

The pandemic has highlighted a myriad of situations within science classrooms that represent extremely disruptive circumstances. What teachers do to transform non-ideal — like social distancing, absenteeism due to illness, masking, and much more — provide the environment in which the teacher works to integrate ideal educational initiatives. Consider science teaching during the pandemic, using the same example from above, a science teacher who values facilitating science investigations regularly in class. The science teacher recognizes that in order to facilitate scientific investigations during the height of the pandemic, they must consider student groupings for social distancing, and available supplies for more and smaller student groups. Additionally, for lesson delivery the science teachers must consider back-up plans if they are required to quickly move to a virtual format or how to successfully facilitate class discussions and communicate while everyone is wearing a mask. Even though a teacher may value science investigations and use pedagogical reasoning to facilitate investigations, the reality of the COVID-19 pandemic and the myriad of circumstances surrounding the pandemic affected their pedagogical actions. Ideal and non-ideal theories address the above situation and provide insight into the background behind a teacher's judgment and the choices made as a result.

Teachers live in a mental world of "ought to": "I ought to grade papers and return them every week", "I ought to debrief every discussion to facilitate further learning", or "I ought to provide more class-time for students to explore ideas and concepts more freely". It is incredibly challenging to reconcile the mental world of the "ought to" with the reality of the "is." From a realist perspective, achievement of a perfect educational scenario is imaginable, but it is not feasible (Valentini, 2012). The research proposed for this paper aimed to provide insight into the struggles and challenges experienced by science teachers during the uncertainty of the pandemic and mental gymnastics between the "ought to" and "is" of the ideal and non-ideal as each teacher wrestled with different realities and resources.

Ideal and non-ideal theories were originally developed in political philosophy when considering the idea of justice. Considering education operates in a world of varying degrees of ideal and non-ideal, I have chosen these theories for their transferability to other fields beyond political philosophy. Ideal in education is the utopian educational scenario all educators strive for, yet realistically will not achieve given the common factors of human behavior and circumstances. In a case-by-case basis the proximity to ideal is always different (Valentini, 2012). Therefore it is impossible to create rules prescribing the level of achievement towards ideal. For example, a science teacher with little resources and knowledge of how to facilitate class in an online environment may seem to be far from the ideal or utopian situation in which their students may thrive in an online environment. A teacher may move closer to the ideal or utopia on the continuum if provided online resources and courses teaching them how to facilitate class online. But is true utopia achievable? There will always be unforeseen technological hiccups and

students who do not participate optimally. This gray area of the ideal/non-ideal continuum is where I choose to focus my research.

Pedagogical judgment and ideal/non-ideal theories work together to encompass the theoretical framework for this hermeneutic phenomenological research study. As teachers navigated their pedagogical judgment in relation to curriculum and instruction the non-ideal theory represents the state of education in which we live and work currently. I chose hermeneutic phenomenology because the method uses a reflective nature in looking at the lived experience. The reflective nature makes it possible for me to delve into the participants' pedagogical judgment when they are working through the non-ideal situations of education.

Assumptions

Due to the constraints placed upon this study as a result of the pandemic, it was not possible to observe science teachers in person. Accordingly, I took an etic approach to examining this phenomenon, analyzing science teachers' perspectives of their experiences and their pedagogical responsibilities to scientific inquiry and equity. Teacher's self-reports of their teaching and pedagogical practices do not always match a researcher's etic perspective (Cohen, 1990). Therefore, the hermeneutic circle addresses the assumptions and biases I have, to reconcile differences in perspective. My study, through an etic approach, provides insight into the many pedagogical judgments a science teacher navigates during unexpected and disruptive situations.

Delimitations

The boundaries chosen for this study aided in simplifying the parameters. I selected participants according to their self-reports indicating commitment to science inquiry and

equity. Due to access limitations in schools during the height of the COVID-19 pandemic, it was not possible for me to observe teachers in person and determine if their teaching methods aligned with the definitions of science inquiry and equity I outlined for this study. However, the Qualtrics surveys, in-depth interviews and follow-up interview, and lesson plans supported teachers' self-reports.

Limitations

There are several limitations that affected the transferability of this study. The study was open to science teachers from across the United States, but the small number of participants meant that I could not ensure that all areas of the U.S. were represented. Additionally, individual states, counties, and cities all responded to the COVID-19 pandemic in a myriad of ways. The specific policies and procedures that teachers responded to depended on participants' locations; this study did not capture the full range of COVID-19 responses that schools enacted. Despite these limitations, I purposely chose a hermeneutic phenomenological approach in order to gather the comprehensive experience of each teacher in this study, allowing for greater transferability of the lived experiences to many areas and regions within the U.S.

For my study, I interviewed participants during the Summer and Fall of 2022, this meant a teachers' recollections of events at the beginning of the pandemic in 2020 could have been somewhat clouded. The hermeneutic phenomenological method specifically chosen for this study allows for in-depth data collection and analysis of each science teacher's recollection of their lived experience during the pandemic. Additionally, follow-up interviews and lesson plans confirmed a teacher's recollections of the experiences during the pandemic.

Ethical Considerations

One of the most challenging factors affecting this study was the accessibility of science educators. During the height of the pandemic, many school districts across the U.S. paused or postponed research of any kind (NCSL, 2021). Now, many school districts still have placed strict guidelines on outside researchers. This was challenging for me to navigate, knowing that there was valuable information to be gathered in relation to experiences during the pandemic, but I also recognized the potential risks — to teachers and students — of conducting research in school districts. Additionally, the pandemic increased many science teachers' workload through added safety measures and changing curriculum and instruction. This increased workload — and the stress it brought —pressed me to conduct my research in the most unobtrusive manner. The purpose of this research was to provide insight into science teachers' lived experiences during the pandemic, not create more work and added stress for the teachers.

Significance

The last time the United States experienced a pandemic with so many interruptions to daily life was the 1918 flu pandemic (CDC, 2019). As educators in 2022, we had not experienced an event so disruptive to daily classroom routines for such an extended amount of time. Navigating the ins and outs of changing school, district, city, and county regulations related to the COVID pandemic were challenging. Considering that today's educators did not or could not have predicted such a large disruption to education, it was likely that most teachers did not have plans for maneuvering through such a scenario.

This study aimed to provide insight into how science teachers continued to teach science during the pandemic. Specifically, I investigated how the teachers — during the

extremely disruptive events surrounding the pandemic — found ways to integrate authentic inquiry opportunities into lessons, while consistently employing equitable practices. The findings from this study benefit many different contributors to science education. This study provides ideas from science teachers for teaching methods to use during future disruptive events. Curriculum writers could develop equitable scientific inquiry lessons and units, based on science teachers' experiences during an extremely unprecedented situation. Teacher educators could use the data collected in this study to prepare future science educators and finally district coaches could use the findings to help entire science departments develop plans for future largely disruptive situations. All of these stakeholders in science education would benefit from this phenomenological study when preparing for science education in a post-pandemic world.

Definitions

There are numerous terms used in discussion of this phenomenological research. Definitions of some of the major terms guide research and ensure consistency in discussion.

Ambitious Science Teaching

Scientific inquiry is an important tenet of Ambitious Science Teaching (AST). As such, I have chosen to additionally define the tenets of AST because I mention these other tenets in Chapters 4 and 5. Scientific inquiry closely aligns with the other tenets of AST, and in my research I found teacher participants utilized their pedagogical judgment to facilitate other tenets of AST during the height of the pandemic, in place of scientific inquiry.

Ambitious Science Teaching is a vision for highly effective science teaching through a set of practices: **planning for engagement with big science ideas, eliciting students' ideas, supporting ongoing changes in students' ideas and joint development of evidence-based explanations** (Stroupe, 2016; Windschitl et al., 2018). The big science idea allows teachers to examine curriculum and standards for related ideas that, grouped together, provide the greatest explanatory power of a topic (Stroupe, 2016). Not every science idea is worth teaching; the practice of identifying a 'big idea' affords the teacher the opportunity to focus on the most important science concepts that students can use for figuring out problems in the world (Windschitl et al., 2018). **Planning for engagement** means identifying and presenting a scientific phenomenon to investigate that is interesting to students while also encompassing a scientific concept that provides opportunity for potent connections to a science topic (Windschitl et al., 2018).

It is important to continually gather students' thoughts on science concepts, especially before beginning a new unit. This information gathering informs the teacher of students' background information related to a science concept. **Eliciting students' ideas** and listening informs teacher judgment about possible curricular moves in response to students' understandings and misconceptions (Windschitl et al., 2018). This discourse provides opportunity for students to engage in academic conversations and organize their thoughts.

Students modify their ideas during science instruction. They compare what they already know and have experienced to the new ideas being presented (Windschitl et al., 2018). Ambitious Science Teaching supports students' changes in thinking through students actively engaging in making sense of the big ideas (Windschitl et al., 2018).

The final step in AST is to **build an explanation**, a hypotheses or model of the big idea experienced throughout the unit. Importantly, this step occurs in exchanges between students and teacher. Teachers reorient students to relevant facts and observations, possible explanations, hypotheses, or models discussed previously, while students synthesize a new explanation of the big idea in light of the new information gathered (Stroupe, 2016).

These last two elements of AST; **modification of student ideas and building an explanation,** encompass the scientific method or inquiry, the method of science teaching largely emphasized by NGSS. Recognizing that AST is a framework with many different elements incorporated to encourage highly effective science teaching, I focused on inquiry methods specifically. By concentrating my research on a smaller portion aligned with the AST framework I was able to research in-depth the elements of inquiry that contribute to highly effective science instruction.

Scientific Inquiry

The process of inquiry in science classrooms follows the scientific method or elements of the scientific method. Four interrelated elements of the scientific method generate understanding of scientific concepts and processes: organizing what we know and would like to know, generating a model, seeking evidence, and constructing an argument (Luft, 2008). These four elements may occur in any order. The process of inquiry mimics the scientific method used by scientists in real-world research.

One of the most important factors of scientific inquiry is the fact that students are conducting the inquiry. This means the teacher acts as a guide and resource while the students are the primary investigators. The teacher's function as guide and resource

provider can be a significant shift in roles for teachers that have not conducted inquiry or allowed students to be the primary drivers in the inquiry. The Next Generation Science Standards recommend the shift to inquiry as the way to teach science (NGSS, 2013).

NGSS and Scientific Inquiry

The Next Generation Science Standards were officially published in 2013. The National Research Council (NRC), the American Association for the Advancement of Science (AAAS), the National Science Teachers Association (NSTA), and Achieve developed the standards to encompass the concepts, practices, and core ideas of science for K-12 across the United States (NGSS, 2013). Currently, 19 states have adopted the NGSS standards, and 21 states have varying degrees of standards based on the NGSS framework (NGSS, 2013). Prior to 2013, many states developed their own standards for proficiency in science, which meant that states had different learning goals for science across grade levels.

The goal for developing the NGSS was to provide guidance to all 50 states concerning the concepts, processes, and crosscutting concepts all students should know for each grade K-12. Before NGSS existed, states focused most of their standards on concepts. NGSS added scientific processes such as observation, question development, planning and carrying out investigations, and analyzing and interpreting data. NGSS also introduced crosscutting concepts such as: patterns, cause and effect, and stability and change (NGSS, 2013).

The NGSS specifies three main dimensions for each grade level: crosscutting concepts, science and engineering practices, and disciplinary core ideas (NGSS, 2013). The crosscutting concepts outline key content in each of the four domains of science:

Physical Science, Life Science, Earth and Space Science, and Engineering Design. The Science and Engineering Practices allow students to experience the scientific method practices common of scientists while investigating phenomena. The Disciplinary Core Ideas encompass important ideas that have broad significance across multiple science or engineering disciplines. Combing the three main dimensions (3-D approach) of the NGSS forms a standard or performance expectation within science, rather than focusing on discrete science concepts or facts (NGSS, 2013).

The 3-D approach requires new and innovative ways of teaching that necessitates teachers focus on processes within science concepts. This change in approach to teaching science requires significant changes to teachers' pedagogical thinking and beliefs while preparing and implementing science lessons. One major area of emphasis that has created a call for significant changes to teachers' instructional practices is the scientific practice of "Planning and Carrying Out of Investigations", commonly known as scientific inquiry. This requires students to formulate a question about a natural phenomenon and develop and carry-out plans for answering the question. Scientific inquiry allows students to experience the scientific method and research in similar ways to scientific research conducted in the real world.

Equitable Science Teaching

American classrooms are increasingly diverse, and curriculum and instruction should account for and include the diversity represented by school and classroom demographics. Equitable science teaching provides a place for all students —especially those who are typically excluded from science fields — to contribute and participate in meaningful ways (Windschitl et al., 2018). Methods implemented to encourage equity in the science

classroom include situating learning within familiar contexts for students, responding to students' individual ideas and experiences, scaffolding for all student abilities, using frequent formative assessments, and honoring students' way of thinking (Windschitl et al., 2018). Incorporating these methods potentially provides an environment in which all students can succeed (Braaten & Sheth, 2017).

Equitable science instruction aims to support and honor the varied identities of all students. This means acknowledging the Eurocentric curriculum and instruction often used in schools, acknowledging the harm Eurocentrism has caused, and taking steps to restore and honor the contributions of Black, Indigenous, and other People of Color (Thompson et al., 2021). By expanding recognition of contributions to science, the classroom is a more equitable environment for all students.

The COVID-19 pandemic placed constraints upon classroom norms and interactions, requiring new and innovative ways of thinking about equitable science teaching. This study aimed to determine what equitable practices science teachers modified and implemented during the pandemic. I recruited participants who strived for equitable science instruction while also recognizing and incorporating practices that lead to equity in the classroom. These pedagogical judgments related to science instruction shape how the teacher makes sense of curricular and instructional steps during unprecedented times, such as the COVID-19 pandemic.

Equitable Learning Opportunities

The "All Students, All Standards" reform found in Appendix D of NGSS documents, refers to equity and diversity initiatives that educators should include while implementing NGSS in the classroom. The NGSS Diversity and Equity team developed the reform "All

Students, All Standards" in order to ensure that NGSS is accessible to all students (NGSS, 2013). Embedded within each standard in the NGSS, the term Equitable Learning Opportunities (ELOs) detail concrete methods for implementing equitable practices and increasing diversity awareness within the classroom (NGSS, Appendix D, 2013).

Equity needs to be more than a singular moment in time or individual endeavor. It takes the entire school system and training to promote and focus on equity (Gallard et al., 2015). Some examples NGSS provide are, introducing scientists and engineers of different social, cultural, and ethnic backgrounds within curriculum and connecting phenomena and problems to local contexts, community, and home environments. Focusing student discussions on classroom investigations allowing all students the opportunity to comprehend and communicate, provided the teacher facilitates the discussions to maximize all students' participation (NGSS Appendix D, 2013). Lastly, explicitly teaching Crosscutting Concepts to help students make connections among science ideas, uncovering interrelated ideas across science disciplines (NGSS Appendix D, 2013). These equitable learning opportunities when combined with professional development for classroom implementation and the involvement of all stakeholders, makes enacting equity more than a singular moment.

Summary

Though we, as a society, were not prepared for the COVID-19 pandemic, it taught us many significant lessons. Looking at the pandemic through the eyes of science teachers and learning from their challenges and celebrating their triumphs will prepare stakeholders for future events in education that could significantly interrupt the classroom

ideals related to scientific inquiry and equity. This study aimed to reveal the lived experiences of a small sampling of science educators, in hopes to gain in-depth insight into the thoughts, processes, negotiations and compromises the teachers made during an extremely stressful life event.

Chapter Two: Literature Review

I explored the combined lived experiences of six science teachers during the COVID-19 pandemic in order to gain a greater understanding of highly effective science instruction under uncertain and unsettling times. Through my research, I illuminated the pedagogical judgments teachers made while navigating classroom moves central to scientific inquiry and equity. The essence of science teachers' pedagogical judgment during COVID-19 provides insight into the choices science teachers made during extreme interruptions to the educational status quo.

To understand how science teachers have exercised their pedagogical judgment related to ambitious and equitable practices, I conducted a literature review looking at current research on pedagogical judgment, ambitious science teaching, equitable science teaching, and teaching during tumultuous events. My review of literature explores the results of facilitating scientific inquiry and equity through a lens of extreme changes and uncertain circumstances. Additionally, I looked at the pedagogical judgment teachers exercised in current research and related the findings to the research questions:

1. What does the lived experience of science teachers during the pandemic tell us about pedagogical judgment during the pandemic and pedagogical judgment in general?
2. How do science teachers navigate their pedagogical judgment in relation to ambitious and equitable teaching?

Theoretical Framework as Applied to the Literature Review

The purpose of my review of literature was to capture the current research findings in science teaching during the COVID-19 pandemic, scientific inquiry and teaching, and equitable science teaching. As discussed in Chapter 1, hermeneutic phenomenology, pedagogical judgment, and ideal/non-ideal theories form the theoretical framework through which I viewed scientific inquiry and equitable teaching. The theoretical framework guided the study I conducted on the lived experience of science teachers during the pandemic and how they exercised their pedagogical judgment in an exceptionally disruptive situation to reconcile the choices made in relationship to scientific inquiry and equity in the classroom.

Pedagogical Judgment

Pedagogical judgment is a concept not often explored in teaching (Horn, 2019), but worth investigating in relation to educational choices made during the COVID-19 pandemic. Understanding the thought processes teachers utilized during the pandemic revealed negotiations of pedagogy and realizations of priorities while intersecting with the extremely disruptive circumstances in education surrounding the pandemic. Pedagogical judgment refers to the choices and responses made by teachers in relation to students, the curriculum, and the teacher's morals (Horn, 2019). Phrased another way: What sort of response or action did a teacher choose when considering the needs of their students in a particular time and space, while staying true to their axiological ideals? This pedagogical choice in action is what happens when the 'usual approach' is not good enough (Stengel & Casey, 2013).

Horn (2019) offers a tripartite view of pedagogical judgment: pedagogical action, pedagogical reasoning, and pedagogical responsibility. This tripartite view details the choices a teacher makes and the reasoning behind the choices, which are rooted in a sense of obligation to principles or situations. Conceptually, there are three elements involved in a science teachers' pedagogical judgment when faced with the tremendous upheaval in the status quo. In Ms. Gringle's thought experiment below, I detail a hypothetical scenario of the tripartite view of pedagogical judgment.

A Thought Experiment: Ms. Gringle's Pedagogical Judgment

The COVID-19 pandemic changed the 'status quo' of teaching significantly across the United States, affecting how and where teaching took place, the amount of time spent teaching, the number of students in a class and how students gathered. Teachers were expected to make new and often unprecedented pedagogical choices when it came to curriculum, assessments, homework, grading, groupwork, lab work, student interactions, communication, and much more. Consider the following scenario: Ms. Gringle aspires to continue offering inquiry-based biology lessons while her classes have shifted to an online format. She teaches at a high school where 70% of the students receive free and reduced-priced lunches, her average class size is 30 students, and the curriculum aligns with Next Generation Science Standards. While developing lesson plans, Ms. Gringle will have to consider many new factors in the delivery of the lesson and participation of the students. Should the lesson occur synchronously or asynchronously? The delivery of the lesson and time will affect how many students will be able to access the lesson. Should she conduct the lesson synchronously so she may take students through the lesson step-by-step, offering advice and answering student's questions in real-time, knowing

many of her students may not attend the synchronous lesson due to time constraints, family/home dynamics, internet accessibility, and other responsibilities? Or should she offer the lesson asynchronously so students may access the lesson when they have availability and internet accessibility, ensuring more students can participate, but knowing that many students will have questions or need clarification about steps within the lesson, and that because of all of this, students may take several days to complete the lesson due to communication time turn-around? Or should she offer both synchronous and asynchronous formats, even though that would essentially double the amount of planning she must do?

Ms. Gringle holds a pedagogical responsibility, part of the tripartite view of pedagogical judgment, to make sure her lessons are accessible to all students (among other pedagogical responsibilities—such as teaching ambitious science). This responsibility affects the choices made in relation to the participation of students, the accessibility of the lesson and the internet, and the support needed from the teacher. All these factors play a role in the pedagogical judgments Ms. Gringle must make during the unnavigated waters of the COVID-19 pandemic.

Once she determines how to deliver the lesson, Ms. Gringle must also consider the extent to which the lesson could incorporate steps of the scientific method or inquiry. This means she needs to consider supplies students are likely to have at home and the safety concerns for conducting an inquiry project at home, perhaps while unattended by an adult. Additionally, she must decide if the inquiry project is rigorous enough to warrant spending several days working on, thus Ms. Gringle is exercising the pedagogical action required in pedagogical judgment to make choices related to her teaching values.

The pedagogical judgment Ms. Gringle must exercise during the pandemic presents new considerations and dilemmas a science teacher may have not experienced previously in their career. These considerations are the basis of my literature review. Most of the literature I found was research literature that was written prior to the pandemic. I used the pre-pandemic research literature to inform the pedagogical judgment science teachers negotiated during this mid-pandemic world. Specifically considering how teachers navigate new educational situations while negotiating elements of their pedagogical responsibilities.

Ideal/Non-Ideal Theories

Less than ideal situations are the core of classroom teaching. Non-ideal theory recognizes that normative ideals do not function perfectly in the real world. It is in the everyday life and the circumstances surrounding the unexpected that we (teachers) test the ideal hypotheses (Jagger, 2018). For example, the ideal of teaching synchronously during the pandemic meets the messiness of real-life situations. Hypothetically, teaching online synchronously should be a perfect solution to teaching during the COVID-19 pandemic, as everyone could remain isolated safely in their own living spaces, access the internet, and join the scheduled class at the appointed time. In the real world, teachers faced many different factors affecting student participation, internet accessibility, technology issues, time conflicts, and access to a safe and quiet space to join class. It is within the less-than-ideal realm of the real world I will be examining the literature for scientific inquiry and equitable teaching.

Hermeneutic Phenomenology

Hermeneutic phenomenology is the overarching theory that brings the whole phenomenon together. While researching the method hermeneutic phenomenology, I consulted van Manen's text, *Researching Lived Experience,* to determine what phenomenologist's say about past literature of similar phenomenon to my study (2016). In van Manen's book he suggests looking at past research literature, especially phenomenological studies of similar nature as a conversational relation (2016). It was with a conversational relation that I considered the existing literature around scientific inquiry and equitable teaching practices. Each research article I found pertaining to pandemic science teaching, scientific inquiry, and equitable teaching was considered in dialogue with the phenomenon of teaching science during the COVID-19 pandemic (2016).

Summary of the Theoretical Framework for the Literature Review

According to the recommendations of van Manen (2016), I put the current research literature in dialogue with the phenomenon of teaching science during the COVID-19 pandemic. Additionally, the intersection of non-ideal theory and pedagogical judgment is where I viewed and assessed the review of literature topics: science teaching during the pandemic, scientific inquiry and teaching, and equity in science teaching. The pedagogical actions science teachers make in relation to science teaching during largely disruptive circumstances such as the pandemic frame the lens through which I aligned the current literature to my research questions. This pedagogical reasoning during an extremely tumultuous event contributed to a rich body of evidence leading to a research study on scientific inquiry and equitable teaching during the pandemic.

Review of Literature Procedure

In order to organize the search for literature relevant to my research topic, I first separated the research into three general areas: science teaching during the pandemic, scientific inquiry and teaching, and equity in science teaching. Then I surveyed each subject area using the Educational Resource Information Center (ERIC) and the American Psychological Association (APA) PsycInfo educational databases. Keywords for each of the three subject areas were used to find relevant research between the years 2013 and 2022. I chose the year 2013 as a parameter because it was the year the Next Generation Science Standards were released, which changed the nature of requirements for science teaching. Additionally, choosing 2013 provided a timeframe for the literature search that would make the quantity of results manageable for my dissertation, given I was searching for literature in several areas. Research prior to 2020 did not address the COVID-19 pandemic and the effects the pandemic had on education, but I have chosen to include research prior to 2020 for the relevant contributions in scientific inquiry, equity, and pedagogical judgment.

Limiting the search to peer reviewed journals and dissertations yielded high quality research articles. Upon abstract review, I eliminated articles if the research did not occur within U.S. schools in secondary science classrooms during instructional time. I also did not include schools in other countries because my research questions pertain specifically to U.S. schools and their response to the pandemic. Journal articles that conducted research outside of secondary science classrooms also would not provide information that would easily align to my research questions. Finally, after-school and summer programs provide a significantly different educational atmosphere than school day instructional

time, making these alternative educational opportunities less compatible to my research questions.

I conducted ancestral searches in articles that aligned significantly with my research questions to find further research that could contribute to the review of literature and provide insight into my research topic, scientific inquiry, and equitable teaching during the COVID-19 pandemic. Combined, all of my search techniques produced a large body of evidence for scientific inquiry and equitable teaching. Given that the COVID-19 pandemic is so recent, very little research has been published about science teaching during the pandemic. As a result, I expanded science to STEM (Science, Technology, Engineering and Mathematics) while searching for studies conducted during the pandemic, due to the lack of results related to only pandemic science teaching. Anticipating the minimal return of studies pertaining to STEM teaching during the pandemic, I used my theoretical framework to examine other tremendously disruptive situations, which would inform what teachers did during the pandemic. Through my review of literature, I found that pedagogical judgment in relation to science teaching had not been researched when considering large disruptions to the educational status quo.

Pandemic Science Teaching

Teaching science during the COVID-19 pandemic looked quite different than the typical science classroom pre-pandemic and teachers approached science education in a myriad of ways. There were many common struggles found throughout the research that made providing highly effective science teaching challenging. Science teachers found managing their time and responsibilities required trade-offs given the new online teaching format implemented throughout school districts in the U.S. (Francom et al.,

2021; Garcia & Weiss, 2020). These trade-offs included less time planning quality science lessons, less time focusing on social-emotional learning (Garcia & Weiss, 2020; Reich et al., 2020) and less time attending to external responsibilities (e.g., family, house upkeep, and meal preparation).

A significant factor affecting the participation of students in online education was the accessibility of the technological resources (An et al., 2021, Francom et al., 2021; Reich et al, 2020), and reduced interactions with students due to disabled video transmission during synchronous lessons and chronic absenteeism (Francom et al., 2021; Reich et al., 2020). Teachers noticed that moving learning to online formats impacted vulnerable populations of students the most significantly (An et al., 2021; Francom et al., 2020; Reich et al., 2020). These vulnerable populations often didn't have the proper technology to access online learning or needed to share technology with several siblings, reducing the time a student had access to class resources. Additionally, students often disabled their video to preserve internet bandwidth, also reducing much-needed interactions with teachers. The inequities experienced by vulnerable populations of students were significantly exacerbated due to the COVID-19 pandemic. It is noteworthy that though these studies mentioned inequities in science education during the pandemic, I did not find studies focusing on providing equitable science education during the COVID-19 pandemic.

Monitoring is one of the cornerstones of a teacher's feedback during lessons: if a student looks confused, a teacher knows a new action must occur to clarify the confusion. The common practice of students' disabling video during synchronous learning made monitoring student's expressions for understanding impossible. Understandably, students

would not enable video during synchronous lessons due to insecurities related to looking at themselves for hours on a screen, peers getting a glimpse of their home life, or possible bullying on social media as a result of class recordings (An et al., 2021; Francom et al., 2021; Garcia & Weiss, 2020; Reich et al., 2020).

Some obstacles and challenges presented in online science teaching included: lack of time management techniques in a new situation and reduced student participation made providing scientific inquiry and equitable teaching even more challenging than pre-pandemic. Some teachers were successful in implementing innovative methods of ambitious science teaching (An et.al., 2021; Hill, 2021). A study by Hill (2021) found that science teachers at an affluent independent school in the south were successful in implementing key features of ambitious science teaching, such as developing and using scientific models to explain phenomena and engaging in debate using scientific evidence. A survey of 107 science teachers in the U.S. conducted by An and colleagues (2021) revealed that 23% of the teachers reported integrating inquiry methods into online learning during the pandemic. The results of the study by An and colleagues (2021) lead me to conclude that the results found in the study by Hill (2021) may be atypical. These two studies, though small in scope, reveal that scientific inquiry and tenets of ambitious science teaching techniques were implemented, but perhaps inconsistently.

Pandemic Ambitious Math Teaching

A significant study in mathematics during the COVID-19 pandemic (Horn & Schneeberger McGugan, 2020) revealed several innovative ways math teachers continued to provide equitable and ambitious teaching. Some teachers made their own instructional videos as a way to encourage connections with students. Others sought regular feedback

from students to inform future teaching. These math teachers also experienced challenges in the quick shift to online teaching. Obstacles included monitoring students for understanding, eliciting student thinking and preserving the integrity of assessments. Noticeably, these teachers are experienced in ambitious and equitable math teaching and approached the shift to online teaching as an opportunity to adapt and learn new techniques knowing there would be a lot of trial and error.

Summary of Pandemic Teaching

Though teachers in several studies reported focusing solely on worksheets (Reich et al., 2020), review work (Francom et al., 2021), and educational videos (An et. al., 2021), it is encouraging to read that some studies (An et al., 2021; Hill, 2021; Horn & Schneeberger McGugan, 2020) report teachers' effort to uphold equitable and ambitious teaching remained during the COVID-19 pandemic. The extreme unknown and immense upheaval of the pandemic, intersecting with the pedagogical judgment exercised by teachers, reveal the choices many teachers made. The teachers' contexts in the atypical studies (An et al., 2021; Hill, 2021; Horn & Schneeberger McGugan, 2020) might have been different than the teachers' contexts where worksheets (Reich et al., 2020) and review work (Francom et al., 2021) were the norm. What sort of contexts are most conducive to implementing scientific inquiry and equitable teaching during the pandemic? Is it possible to implement scientific inquiry and equitable teaching in many different contexts during the pandemic? In my study, I recruited secondary science teachers from several different teaching contexts, which provided some answers to these questions. The findings from my review of literature lead me to conclude that my

research study aimed to answer some complex questions, in which there is not much current research literature.

Scientific Inquiry

Scientific inquiry mirrors the scientific method commonly used by scientists in real-world research and allows the students the opportunity to generate evidence and thus new ideas or models to explain phenomena (Luft et al., 2008). The Next Generation Science Standards (NGSS) emphasize inquiry as a focal point of delivery for scientific phenomena (NGSS, 2013). I focused my review of literature to the practice of inquiry as it relates to ambitious science teaching, mentioned in Chapter One, and aligns with the Next Generation Science Standards.

Through my review of literature, I found several themes that may affect the implementation of scientific inquiry during the COVID-19 pandemic. Studies revealed that teachers are often confused about what inquiry is, how to involve students in inquiry, and the importance of inquiry in relation to AST and NGSS. Highly effective science teaching is challenging, even when not in the midst of a pandemic. The findings from my review of literature informed my understanding of scientific inquiry and equitable teaching during extreme changes to the status quo.

Several of the studies related to professional development in scientific inquiry found that teachers often report implementation of inquiry in their classrooms, but observations reveal that teachers implemented hands-on activities, rather than genuine inquiry (Lederman et al., 2014; Kazempour & Amirshokoohi, 2014; Lotter et al., 2018). Developing communities of practice among science teachers to discuss and share inquiry methods allowed teachers to focus on implementing rigorous inquiry in the classroom

(Lotter et al., 2014) and move away from hands-on activities. The studies also indicated that professional development and communities of practice increased the implementation of inquiry, the confidence of teachers implementing inquiry, and a gradual change in pedagogical content knowledge towards scientific inquiry (Lederman et al., 2014; Singer et al., 2016; Stroupe et al., 2021).

In my study, I looked for evidence of science teachers' facilitating opportunities for students to be the leaders in scientific inquiry rather than the teacher being the leader. In the semi-structured interview science teachers who focused on inquiry would provide examples of lessons and activities where students conducted the scientific method, and evidence-based discussions occurred, after students had opportunity to explore the science phenomena.

Allowing students to be the experts when conducting different elements of scientific inquiry was a common challenge experienced in the studies (Kazempour & Amirshokoohi, 2014; Lesseig et al., 2016; Miller et al., 2018). This meant more classroom time was spent developing investigations (Lotter et al., 2018). But the pay-off meant students increased their use of AST practices, such as scientific discourse and data driven explanations. (McLaughlin & McFadden, 2014; Singer et al., 2016). With the increase in rigor through inquiry and elements of AST, students persevered and were more motivated and empowered through the challenging lessons (Lesseig et al., 2016).

The studies on scientific inquiry and AST reported an increase in authentic implementation and a gradual change in teachers' pedagogical content knowledge. The stress of the COVID-19 pandemic provided a testing ground for true change. When an extremely unsettling situation occurred, did teachers rely on their pedagogical content

knowledge and communities of practice to implement highly effective science teaching? The studies show that when teachers are willing and able to implement scientific inquiry and elements of AST, students were more motivated and felt more empowered. The pedagogical judgment that teachers exercised during the uncertainty of the COVID-19 pandemic showed scientific inquiry and elements of AST continued but took form in many different ways.

Equity in Science Teaching

Equity in science teaching is a moral imperative, not just an act of kindness for students that 'need help' (Windschitl et al., 2020). Equity in science teaching is the practice of providing means for *all* students to participate and contribute in meaningful ways in a learning environment (Windschitl et al., 2020). This is especially important for students who are often excluded from — or pushed out of —rigorous science instruction, including girls and non-binary students, students of color, and students with disabilities. Thus, it was necessary to include equity in science teaching as its own topic in my review of literature. Incorporating equitable practices during the COVID-19 pandemic were challenging (An et al., 2021; Garcia & Weiss, 2020; Horn & Schneeberger McGugan, 2020; Reich et al., 2020). The studies included in this review of literature reveal the necessity and benefits of including equity in science teaching, especially during the enormously disruptive context of the COVID-19 pandemic.

For science teaching to be equitable, students must have autonomy in their learning (Kolonich et al., 2018; Nasir & Vakil, 2017; Patterson, 2019). The studies in my review of literature found that allowing students the opportunity to make choices about their learning, to discuss their learning, and to be the knowledge-generators during learning

provided an environment in which all students were contributors and successful learners. This means the teacher should assume the role of facilitator and allow students the opportunity to be the knowledge-generators. This changes the goals of teaching from disseminating knowledge to facilitating learning, and removing the authoritative position of the teacher (Kolonich et al., 2018). Interestingly, in several studies, when a teacher shifted their role to facilitator, they viewed the students as more capable of being knowledge generators (Kazempour & Amirshokoohi, 2014; Lesseig et al., 2016).

One of the key features of AST is the opportunity for students to engage in scientific discourse (Singer et al., 2016). Eliciting student ideas and engaging students in scientific discussion provides an environment where students are active knowledge-generators. The NGSS appendix titled 'All Students, All Standards' references the need for science teachers to provide equitable learning opportunities for all students in science (2013). The 'All Students, All Standards' appendix emphasizes, like AST, the necessity of scientific discourse to reinforce learning. Students need opportunities to discuss their learning. When students engage in scientific discourse with peers the students become the authorities and owners of their knowledge, rather than passive learners (Nasir & Vakil, 2017).

As authorities of their learning, students take an active role. A case study by Nasir and Vakil (2017) showcased a curriculum where students were the authorities in relation to the teaching and learning activities in the classroom. Providing a space for the students to be the authorities also then allowed the students to resist racialized and gendered stereotyping and share scientific ideas in a more equitable way. Opportunities for

students to be the authority allows students the space to make sense of their learning through their own experiences and generate knowledge through their own world view.

How can teachers continue to exercise equitable practices during the COVID-19 pandemic? Students need autonomy in their scientific educational journey, room to be the authority, and the space to engage in scientific discourse with peers to make sense of learning through their experiences. The pedagogical judgment teachers exercised during the pandemic in relation to equity showcased *how* teachers were thinking about equity and *why* it was important to consider during the tremendous changes and interruptions during the COVID-19 pandemic.

Implications for Research

Looking at my research study, it was important to examine the pedagogical judgment teachers exercised during the uncertain and constantly changing circumstances they encountered during the COVID-19 pandemic. I examined the types of lessons science teachers planned. Did the teachers take into consideration the equitable practices used prior to the pandemic? Were new creative methods incorporated? Or was there a mixture of both? Maybe the extreme upheaval and uncertainty of the pandemic only allowed for survival mode — such as review lessons (Reich et al., 2020) and worksheets (Francom et al., 2021) — since teachers and students were emotionally and mentally taxed. What sort of pedagogical judgments led to those choices?

Highly effective science teaching looked incredibly different during the pandemic. Pre-pandemic teachers might have planned for big science ideas and how to embed authentic inquiry (Singer et al., 2016; Windschitl et al., 2020). During the pandemic, students had limited access to scientific supplies (An et al., 2021, Francom et al., 2021;

Reich et al, 2020). Utilizing pedagogical judgment during this period of intense upheaval, teachers modified scientific inquiry significantly to provide doable and safe inquiry opportunities that students could participate in at home (Allaire et al., 2022), and utilized interactive software to incorporate inquiry online (Hill, 2021). Other options teachers chose included eliminating scientific inquiry completely and providing interactive science websites for reinforcement of ideas (An et al., 2021; Hill, 2021). The web of decisions teachers made in relation to highly effective science teaching contributes to a rich explanation of the lived experience of science teachers during such a tumultuous time in education.

Summary

Through this review of literature, I looked at scientific inquiry and equitable teaching through a lens of uncertainty and disruption, as it relates to the pedagogical judgment that teachers exercise. There are a myriad of ways to think of and implement scientific inquiry and equitable practices, some more easily transferrable to extremely disruptive situations than others. The pedagogical judgment teachers exercised in relation to scientific inquiry and equity during the COVID-19 pandemic contribute to a rich description of the lived experience of teachers during such an unprecedented time.

Chapter Three: Method

The purpose of this study was to delve into the lived experience of secondary science teachers during the COVID-19 pandemic, specifically focusing on teachers' pedagogical judgment related to scientific inquiry and equity. This chapter details the research method design, rationale, and my role as researcher in a hermeneutic phenomenological study. I also explain the sampling techniques used for participant selection. A semi-structured interview protocol was my chosen method for exploring the experiences of the participants to answer the following research questions:

1. What does the lived experience of science teachers during the pandemic tell us about pedagogical judgment during the pandemic and pedagogical judgment in general?
2. How do science teachers navigate their pedagogical judgment in relation to ambitious and equitable teaching?

In this chapter, I explain the Qualtrics survey, semi-structured interview protocols and follow-up interview developed for the study along with the subsequent analysis of the semi-structured interview and other data collection instruments. I also present validity, reliability, and ethical considerations along with a summary of the research methodology chosen for this study.

Design and Rationale

I chose a hermeneutic phenomenological approach for this study because it allowed me space to illuminate rich descriptions and personal meanings of the lived experiences of secondary science educators as they navigated pedagogical judgment related to scientific inquiry and equity during the COVID-19 pandemic. I considered a case study approach, which allows for the development of detailed accounts of multiple cases, but it does not fully recognize the lived experience of the participants. Hermeneutic phenomenology is the study and interpretation of the lived experience of a group of individuals around a common phenomenon (Creswell, 2018). Martin Heidegger first developed hermeneutic phenomenology as a framework for looking at a phenomenon through a set of lenses while circling back to preunderstandings of the phenomenon to synthesize new understandings (Peoples, 2021). This process, known as a hermeneutic circle, affords the researcher opportunity to make their personal biases and judgments explicit prior to analyzing data (Peoples, 2021). After I analyzed the data, I then circled around to the prior understandings of the phenomenon and reassessed. This aided in interpreting an individual lived experience for each participant. By merging the lived experience of each individual participant's viewpoints, the essence was revealed by conveying the phenomenon as a whole (Billups, 2021).

Researcher's Role

My role as researcher was to uncover the essence of the phenomenon of teaching science during the COVID-19 pandemic and the negotiations teachers experienced related to their pedagogical ideals. As a former science teacher and current science teacher educator, some of the participants were familiar to me. I suspended any

hierarchical relationships with participants by focusing entirely upon the research and lived experiences of the participants.

Having taught secondary science for 10 years and working as a science teacher educator for 4 years, I have developed biases concerning science teachers' pedagogical stances. Some of my biases include the commitment to facilitate scientific inquiry online. I have developed and published lessons for primary and secondary science detailing how to incorporate scientific inquiry in an online setting (Allaire et al., 2022). Using the hermeneutic circle, I observed each teachers' experience through separate lenses, considering the context the teacher was currently in, then reexamined my understandings of pedagogical judgment, curriculum, and instruction through the teachers' context. Following the hermeneutic circle helped me develop a new working comprehension of the essence of science teachers' pedagogical judgment through their teaching context, pertaining to equity and scientific inquiry during the height of the pandemic.

Participants

I recruited secondary science teachers who taught in the United States. The criteria for enrollment in the study also included a minimum of three years teaching experience and pedagogical responsibility to equity and scientific inquiry. The teacher participants each had a minimum of three years teaching experience to provide a depth of teaching experience during the previous two years of the COVID-19 pandemic and a year of experience teaching prior to the start of the pandemic.

The heart of this study revolved around teachers' commitments to scientific inquiry and equitable practices in their teaching techniques, instructional moves, and interactions with students. This meant the teacher desired to facilitate scientific inquiry and equitable

methods in their teaching practice regardless of overall climate during the height of the pandemic. Both scientific inquiry and equity were fundamental to the theoretical framework of hermeneutic phenomenology, pedagogical judgment, and non-ideal theory for my study. A science teacher who desired to uphold the basic framework of scientific inquiry and teaching, during the COVID-19 pandemic, was the target participant for this study.

Once a science teacher had agreed to participate in the study, it was necessary to determine if their teaching pedagogy aligned with the scientific inquiry and equitable practices I researched for this study. Interested teachers were sent a Qualtrics survey (Appendix A) to determine alignment. If a teacher's answers to the survey aligned with the principles on the questionnaire, I scheduled a time for a semi-structured interview (Appendix B). The semi-structured interview consisted of open-ended questions, providing participants the opportunity to detail their experiences teaching during the pandemic.

The sample size for the study was six secondary science teachers. This was determined according to the suggested sample size for a typical phenomenological study of 5-25 participants (Creswell, 2018). Using the detailed participant criteria, sampling process and sample size for this study ensured quality in-depth data pertaining to science teachers' lived experiences during the pandemic.

Recruitment

Recruitment for the study occurred through purposeful sampling followed by snowball sampling (Creswell, 2018). I began recruitment with email inquiries to former students in the teacher educator program of a mid-size university in a mountain west

state, and social media and professional organization inquiries. Appendix C includes a sample recruitment email and Appendix D is a sample of the research study flyer I posted on social media. I employed the snowball technique to enroll further participants by asking current interested participants if they were aware of other science teachers who fulfilled the criteria for the study. Unfortunately, none of the teacher participants referred other science teachers.

In my study, originally, I aimed to interview 8-9 secondary science teachers. After four months of advertising my research study I had interviewed 6 participants. Given the broad reach of my advertising across the United States and the four months spent soliciting science teachers through multiple avenues, it became clear that I would not obtain more participants. Additionally, I desired to interview participants fairly recently after the height of the 2020-2022 COVID-19 pandemic experience because people's detailed recollection of events begin to fade. As a result, time played an important factor in ceasing recruitment of participants after completing interviews with six participants.

Advertising Avenues

I advertised my research study through the following avenues:

1. Social media posts: twice two months apart on both Instagram and Facebook. I also requested that friends on the two social media platforms repost my research flier on their Facebook and Instagram pages to widen the visibility of my study. I am aware of five educator friends completing my request.
2. Professional education associations: my research flier (Appendix D) and a brief description of my study were posted or distributed by email listserv to The American Association for Teaching and Curriculum, Association for Science

Teacher Education twice several months apart, the American Association of Chemistry Teachers, a Pacific Northwest professional teacher site, the Homewood Science Center in Illinois, and related teacher networks in Chicago, and a New England professional teachers association site.

3. I obtained the contact information of former students in a local Mountain West teacher education program who pursued a secondary science licensure between 2016 and 2020. I emailed each student individually and the Teacher Education Program Field Placement Coordinator followed-up with an email to each student as well.
4. I emailed former teacher education program participants' mentor teachers the details of my research study as well.
5. I also conducted snowball sampling by asking each participant if they would refer any other teachers whom they thought might be interested in participating in my research study.

Participant Demographics

The demographics of the six participants were diverse, which resulted in a broad range of experiences during the pandemic. There were two men and four women, with teaching experience ranging from 3 years to 28 years. Three participants were no longer teaching at the time of the interview, with one leaving after the first year of the pandemic. Five participants taught at the high school level; one participant taught at the middle school level during the height of the pandemic. One participant taught at a private school and the other five taught at public schools. The teacher participants' geographical

locations in the United States encompassed four regions: Mountain West, Midwest, East Coast and New England.

Table 1: Participant Demographics

Name*	Gender	Years Teaching	Public or Private School	Middle or High School	Geographic Location	No Longer Teaching
Anna	Female	11	Public	High	Midwest	
Bella	Female	5	Public	Middle	Mountain West	X
Carol	Female	28	Private	High	New England	
Ray	Male	3	Public	High	Mountain West	X
Sally	Female	11	Public	High	East Coast	X
Seth	Male	17	Public	High	East Coast	

**All proper names are pseudonyms*

Instrumentation

The Qualtrics survey I developed and sent to interested participants helped determine science teachers' pedagogical alignment with scientific inquiry and equity. Included in the questionnaire were portions of an instrument, Pedagogy of Science Teaching Test (POSTT; Cobern et al., 2014; Schuster et al., 2017). This instrument was developed to determine a science teacher's pedagogical tendencies in relation to 100 different teaching scenarios (Cobern et al., 2014). The focus of the scenarios was to reveal teachers' possible instructional moves with varying degrees of scientific inquiry or direct instruction. The responses teachers provided to the instrument's teaching scenarios allowed for the interpretation of teaching orientation concerning scientific inquiry and direct instruction.

A research team at the Mallinson Institute for Science Education at Western Michigan University developed POSTT. The research team also made the instrument free for

general public use. The items in the POSTT instrument may function alone; research shows that teacher participants can put themselves in the scenarios to make pedagogical decisions regardless of the science discipline or grade (Cobern et al., 2014). The POSTT instrument has been determined to be reliable and valid through several successive research projects, making the POSTT instrument an ideal fit for my study (Schuster et al., 2017).

To determine if an interested participant held equitable ideals, I used a modified version of the Views of Students' Mathematical Capabilities (VSMC) instrument (Jackson et al., 2017)[2]. While VSMC was initially developed to gauge mathematics teachers' understandings of equitable instruction, the three open-ended questions of the VSMC were easily transferrable to other subject areas beyond mathematics. Determining the participant's motivational framings in regard to students' capabilities in the classroom, was a key indicator of equity practices. For instance, a teacher's response to the question, "In your own classroom, when students don't learn as expected, what do you find are the reasons?" provided insight into a teacher's diagnostic framing of situations in the classroom (Jackson et al., 2017). Diagnostic questioning involves determining the cause of the problem. (Jackson et al., 2017). Prognostic questions such as, "What do you [the teacher] do in response to students not learning as expected?", involves the identification of solutions to a problem. A teacher could provide a productive or non-productive response to diagnostic or prognostic questions. I coded the diagnostic and

[2] Permission to use the VSMC instrument for this study was granted by Dr. Kara Jackson via personal communication.

prognostic questions, and analyzed an interested science teachers' responses to the VSMC to determine their tendencies towards productive or unproductive responses. General tendencies towards productive responses indicated a teachers' leanings towards equitable ideals thus aligning with the equitable practices I researched for this study.

Upon teachers' completion of the Qualtrics survey (Appendix A), I coded the responses to determine general leanings towards scientific inquiry and equity. This meant that at least two of the three POSTT responses were inquiry-oriented and two of the responses to the three VSMC questions were productive[3] in nature. The respective values, two POSTT responses and two VSMC responses ensured a majority of the responses were inquiry and equity oriented.

The POSTT instrument provided a coding scheme to determine if a teacher's response was inquiry or didactic oriented. Each item on the POSTT also prompted the teacher to provide rationale for their response. Coding for the VSMC required determining if a participant's response was productive, unproductive, or mixed. I considered a VSMC item productive if the teacher's response included a description of the student's performance in relation to instructional and/or schooling opportunities. Following Jackson and colleagues' (2017) framework, if a response tied student performance to an attribute of the student or something other than instructional and schooling opportunities, I coded the response as unproductive. If a response included a combination of productive and unproductive explanations for a student's performance, I

[3] If an interested participant provided a mixed response to one of the survey questions, with both productive and unproductive answers to a question, this was considered a productive response. The reason for this determination was because the interested participant did provide a partial productive answer.

coded the response as a mixed response. For each instrument, POSTT and VSMC, I provide further detail of their respective analysis schemes, in the data analysis section of my study.

One semi-structured interview with a follow-up interview formed the bulk of the data collection techniques developed for my study (Billups, 2021; Peoples, 2021). The semi-structured interview took approximately 60 minutes for each teacher to complete, with two teachers spending 120 minutes detailing their experience. The follow-up interview took 15-20 minutes to complete, depending on the number of interview questions that needed further details.

I followed a semi-structured protocol suggested for phenomenological studies according to Billups (2021) in *Qualitative Data Collection Tools: Design, Development, and Applications* (Appendix B). In response to initial interviews that contained information that was unclear, or where misunderstandings and/or misinformation occurred, I developed questions to gain further clarifying details in the follow-up interviews (Peoples, 2021). Artifacts such as lesson plans provided additional data, ensuring that a combination of instruments provided rich findings for my study (Billups, 2021; Peoples, 2021). Teachers' lesson plans also provided insight into scientific inquiry and equity methods planned for implementation, thus giving me a picture of how teachers envisioned scientific inquiry and equity in their classrooms.

The final form of instrumentation I used in my study was journaling while following the hermeneutic circle model. I completed one journal entry after each semi-structured interview and three additional journals which contained overall conclusions of the data collection thus far. This allowed me to reinterpret my understandings of teachers' lived

experiences continuously. Additionally, using the hermeneutic circle to interpret and develop new understandings of scientific inquiry and equitable teaching provided depth to the essence of science teaching during a pandemic.

Timeline

After I obtained Institutional Review Board (IRB) permission in July of 2022, teacher recruitment occurred during the latter part of the summer of 2022. Upon agreement to participate, each teacher was sent the Qualtrics survey (Appendix A) to determine eligibility for the study. I followed the Qualtrics survey with a semi-structured interview if a teacher's responses to the Qualtrics survey aligned partially with scientific inquiry and equitable teaching ideals. All interested science teachers were emailed the same open-ended questions prior to the interview (Creswell, 2018). The six teacher participants chose to conduct the semi-structured interview through Zoom. All of these steps occurred between mid-July and early October of 2022.

Follow-up interviews and artifact collection took place from late July to mid-October of 2022. After journaling, transcribing and holistically reading the semi-structured interview responses (Billups, 2021; Peoples, 2021), I conducted follow-up interviews to clear-up misunderstandings and gather missing information. Teacher participants also provided an example lesson plan to support their attestation of utilizing scientific inquiry and equity practices during the height of the COVID-19 pandemic. I analyzed lesson plans and other provided artifacts for evidence of equitable practices and scientific inquiry methods towards the end of the summer and into the Fall of 2022. Coding and analyzing of collected data: interview responses, lesson plans, and journals began in the Fall of 2022. Once I had analyzed all the data, I developed a synthesis of the lived

experience of science teachers in the Winter of 2022-2023. Final edits began in the Winter of 2023, followed by a dissertation defense in the Spring of 2023.

Data Collection

If a teacher had expressed interest in contributing to my research study, after obtaining verbal confirmation of their agreement to participate, I would email the teacher the six question Qualtrics survey. The teacher could complete the Qualtrics survey on their own time by using a provided email link to privately access the survey. Once the teacher completed the survey, I would receive an automated email from the Qualtrics program. I could then view the teacher's responses and begin analysis to determine if their ideas of scientific inquiry and equitable teaching aligned with the definitions for my study. I obtained verbal confirmation of agreement to participate from seven interested science teachers. Six of those science teachers completed the Qualtrics survey. After analyzing the six Qualtrics surveys, I determined that the responses the teachers provided aligned with the definitions of scientific inquiry and equity I had outlined for this study. Therefore, the six science teachers who completed the Qualtrics survey were the six science teachers who contributed to my study.

The first interview with each teacher participant was a 60 minute open-ended interview. Prior to beginning the Zoom recorded interview, I asked the teacher participants to share any personal stories, experiences, feelings and/or anecdotes that came to mind, during the interview. Two teacher participant's interviews were longer than 60 minutes. At the 50-minute mark I checked-in with both participants to let them know we were getting close to 60 minutes, and I wanted to honor their time. Both participants replied that they were OK with the interview taking longer than 60 minutes.

The other four teacher participants spent approximately 60 minutes answering all of the interview questions. At the conclusion of the interviews, I let each teacher participant know that I would take approximately 2 weeks to transcribe the interview and provide the transcription via email for them to check for accuracy.

The follow-up interview took place approximately 2 weeks after the semi-structured interview for all 6 participants. The participants received the transcript of their semi-structured interview prior to the follow-up interview, with instructions to check the transcription for accuracy and provide feedback as to any comments they would like to have omitted or expanded. If there were words, phrases, or ideas that did not make sense during my transcription, I would make a comment in the margins that I needed clarification during the follow-up interview.

The purpose of the follow-up interview was mostly to confirm the accuracy of the interview data from the semi-structured interview and allow the teacher participant the opportunity to request the omittance or expansion of any information they originally disclosed. Two of the teacher participants requested to omit some of the potentially identifiable information they provided in the semi-structured interview, even though the teacher participants were aware that I would deidentify all data they provided. Additionally, two of the teacher participants expanded their explanations of scenarios in order to provide further rationale for their decisions and actions. In each transcript, I provided pseudonyms for each teacher's name, school, and district. If a teacher participant provided any other identifying information, such as a student's name, or the post-secondary school they graduated from, I either omitted the information or provided a pseudonym.

To support the teacher participant interviews, I requested that all participants provide a lesson plan they implemented during the pandemic. Some participants provided very basic one-page descriptions of their weekly plans. Others provided 6–7-page lesson plans with the concepts tied to NGSS, and teacher moves explicitly detailed. One teacher participant (Seth) did not provide lesson plans, after I had emailed them three times requesting the plans. The teacher participants who provided extremely detailed lesson plans taught at turnaround schools where the state provided lesson plan templates and the teachers submitted plans bi-weekly to administration. The findings from the lesson plans, in support of the lived experience of science teachers, is detailed in the essential themes section of Chapter 4.

Data Analysis

The coding and analysis of the Qualtrics survey included coding for three POSTT items and three VSMC questions. Both instruments provided coding and successive analysis of the items/questions. The POSTT items had four possible responses. Each response aligned with a teaching method commonly employed in science instruction; didactic direct, active direct, guided inquiry and open inquiry (Appendix E). Each item also solicited the teacher to explain why they chose the response they did. Combining a teacher's response and reasoning behind the response contributed to the analysis of a teacher's tendency towards direct or inquiry-oriented teaching. If two of the three responses indicate a teacher's leanings towards inquiry, then I considered the teacher for the study, as long as their responses on the latter part of the Qualtrics survey indicated a tendency towards equity.

Teacher's responses to the three VSMC items on the Qualtrics survey required some interpretation as the scheme provided assumes an active interview role rather than an online Qualtrics survey, like I used. In an active interview role the interviewer could ask follow-up questions to an interviewees responses if the original response needed further explanation or clarification. Due to the static nature of the Qualtrics survey, I did not have the opportunity to ask follow-up questions if needed. This meant I needed to interpret the overall response to a question as productive, unproductive, or mixed based on the information provided on the survey. Appendix E provides a scheme for determining if a response to one of the VSMC items was a productive response, unproductive response or mixed. I determined teachers' total survey response productive if I coded two of their three items on the Qualtrics survey as productive or mixed.

In summary, I considered a teacher for the study if they provided two responses on the Qualtrics survey that indicate a tendency towards inquiry and two responses that indicate a tendency towards equity. I developed these parameters to ensure alignment with the major features of my study. Alignment with the study ensured rigor and depth of the participant's successive semi-structured interviews, thus contributing to a robust interpretation of the lived experiences of science teachers during the pandemic.

The analysis of the semi-structured interviews took place holistically. I chose to engage deeply with each participant's data, through a thorough reading of each semi-structured interview 5 times (van Manen, 2014). This method of reading each interview in an empathic way ensured that I considered all the details in order to reveal the essence of the phenomenon (Peoples, 2021). I then highlighted significant statements from each interview and grouped all the significant statements according to ideas (Creswell, 2018).

Next, I examined all of the ideas, across the six participants' data, looking for commonality. The prominent ideas mentioned throughout became the six essential themes.

After I determined the six essential themes, I analyzed the Qualtrics surveys and lesson plans to determine if there was confirmation or disconfirmation of the themes. The Qualtrics surveys and lesson plans provided valuable confirmation of scientific inquiry and equitable practices, which I included in the discussion of findings. I then combined the six themes to construct a description of *what* the participants experienced with the phenomenon (Creswell, 2018). The atmosphere and tone I noted in my journals, after each interview, contributed to the *how* of the phenomenon. Finally, I drafted a composite description of the lived experiences of the participants using the *what* and the *how* to develop the essence of the experience.

Journaling after each interview helped me examine my biases according to the hermeneutic circle. Each interview was read several times while journaling; during each reading I typed my thoughts in relation to parts of the interview that were most interesting and relevant to my study. I also made a point to describe the overall atmosphere of the interview and the specific tone a teacher participant used in response to interview questions. Once each interview had been read and I had journaled my understanding of the interview responses several times, I read my journal entry to begin building a new understanding of the science teachers' lived experience during the pandemic. The new understanding gained from journaling contributed to an overall understanding of the essence of science teaching during a pandemic.

I analyzed the lesson plans provided by teacher participants using a table to record and synthesize the information (Appendix F). According to the convergence towards and divergence from ambitious science teaching, looking for specific examples of scientific inquiry, and equitable teaching practices, I recorded evidence from the lesson plans on the table (Billups, 2021). This convergence and divergence data was incorporated into the essence of the experiences of the science teacher participants during the height of the pandemic. The purpose of including the evidence collected from the lesson plans was to provide depth and corroboration of the lived experience of science teachers'.

Combining all the synthesized data from the Qualtrics survey, in-depth science teacher interviews, journal entries, and lesson plans produced a strong picture of the lived experiences of science teachers during the COVID-19 pandemic. The composite of this data analysis contributed to a strong synthesis of how, and to what extent, ambitious science teaching and specifically scientific inquiry, and equitable teaching occurred during the pandemic. A strong analysis allows for more opportunity to transfer the results of this study to other areas of science teaching during intense uncertainty and interruption.

Validity

One of the many roles as a researcher is the responsibility to ensure the accuracy of the qualitative information (Creswell, 2018). Creswell and Poth (2018) recommend using at least two validation strategies. I have utilized three validation strategies to aid in the credibility of the results of my research: triangulation of the data, rich descriptions of the phenomena and member checking to confirm the validity of the information contained in this study. I used triangulation of the data collected during the study to corroborate all the

different data sources. For example, the Qualtrics survey responses and collected lesson plans reinforce the findings from the semi-structured interviews. The rich descriptions aid in the transferability of the phenomena and member checking confirms the accuracy of the interview data.

The triangulation of data included the Qualtrics surveys, a semi-structured participant interview, and provided lesson plans. I looked for confirmation and disconfirmation of the essential themes in the Qualtrics surveys and lesson plans to support the findings in the semi-structured interview. The two salient themes that address my second research question, *Thoughts on Equity* and *Facilitating Ambitious Science Teaching*, were present in all of the participants' Qualtrics surveys and 5 of the lesson plans. One participant did not provide lesson plans.

To assure validity of the four other themes, *First Impressions of the Pandemic, Confusion of the Pandemic, a New Normal, and Technology as Aid and Hinderance,* I provide a rich description of each participant's experience within their lived context. The context provided in the individual narratives and the six essential themes are complex and reveal a multifaceted experience for each participant (Peoples, 2020).

Additionally, according to Creswell and Poth (2018) providing a rich description requires revisiting the raw data soon after collection to add further descriptions that might be helpful during the analysis. While journaling after each interview I made sure to provide details such as the tone a participant used in response to questions and the overall atmosphere during the interview.

In following the hermeneutic phenomenology methodology, and according to the recommendation of Peoples (2021) and Billups (2021), I conducted member checking via

confirmation of the semi-structured interview transcripts. I provided the participants with the transcript of their semi-structured interview to read and check for accuracy. I also embedded comments in the transcript where I asked the participant for further clarification of an idea if, during transcription, it was unclear. Then, during a phone conversation with the participant, I verbally confirmed the results of the transcription. Throughout the conversation participants had the option to remove any information they did not want shared. I also confirmed any clarification they had provided in the comments of the transcripts.

The triangulation of data, member checking, and rich descriptions of phenomena ensure validity of the data and interpretations, resulting in a descriptive explanation of the phenomena, teaching secondary science during the COVID-19 pandemic. The triangulation of the semi-structured interviews, Qualtrics survey and lesson plans confirmed that scientific inquiry and equity were salient throughout all data points. Additionally, I felt it was important for the teacher participants to confirm the accuracy of their interview transcripts and allow them the opportunity to revise any comments they made. Lastly, the rich descriptions technique brought to light all of the nuances within the phenomena experienced by the participants. Combined, all of these techniques produce a rigorous interpretation of the phenomena, teaching secondary science during the COVID-19 pandemic.

Reliability

To make my preconceptions explicit, I journaled my thoughts and assumptions after each semi-structured interview (Peoples, 2020). In these journals, I wrote my thoughts about a participant's experience prior to reading the transcript or dwelling on their entire

experience as a whole. One of my lasting first impressions after each interview was that each participant was 'just doing what they could to survive teaching.' After a continued immersion in each interview, I concluded that the participants were incredibly resilient educators who made every effort to integrate scientific inquiry and equitable teaching during the height of the pandemic. Their integration of scientific inquiry and equitable teaching was creative and made a lasting impression on their teaching pedagogy. This was apparent through their comments at the end of their interviews. Each teacher participant found positive aspects of the pandemic, whether it was through using technology in creative ways to increase communication and build bonds amongst students or experiments that incorporated inquiry in new ways.

Ethical Considerations

Participants were advised to their rights to privacy, as well as their right to withdraw from the study at their own request. I informed all participants of the purpose of the study, and I obtained informed consent prior to beginning the interviews (Appendix G). I preserved all participants' confidentiality by providing pseudonyms for all participants, schools, and districts. Additionally, at the request of one of the participants, I did not disclose teachers' titles (e.g., Biology teacher, Chemistry teacher, etc.). To prevent harm to any participants, I took care in determining if they had any objections to the nature of the study or believed that participating caused a negative impact as a result of contributing to the study. I saved all data collected from the study on a password-protected storage device, utilized only by me.

Summary

The research design chosen for this study was carefully selected to capture the lived experiences of science teachers most succinctly during the height of the pandemic. The combination of Qualtrics surveys, semi-structured interviews and collection of lesson plans provided a strong assemblage of evidence to develop an essence of the lived experience for science teachers, specifically targeting their pedagogical judgment during the pandemic. Bringing the lived experiences to light will inform stakeholders of the many choices and compromises a science teacher makes regularly in relation to their pedagogy. Under the extreme situation of a pandemic or other life-altering events, being aware of the pedagogical judgment science teachers exercise will contribute to resources for future life-altering events.

Chapter Four: Research Findings and Discussion

In Chapter 4, I present the research findings and connect the findings of the study with hermeneutic phenomenology, ideal/nonideal theories and pedagogical judgment. The data collection and analysis, using hermeneutic phenomenology; is an interpretive process in which philosophers agree there is not a succinct step-by-step process; it is a carefully cultivated thoughtfulness rather than a technique. Phenomenology has been called a method without techniques (van Manen, 2016). I discuss the manner in which I collected data and analyzed the information that led to rich descriptions of each individual participant's experiences. In addition, I interpreted the essential themes found in all of the participant interviews, Qualtrics surveys, and lesson plans, along with an overall general narrative of all the participants' experience of teaching secondary science during the COVID-19 pandemic.

According to van Manen, a philosophical leader in hermeneutic phenomenology, our concern is to discover aspects or qualities that make a phenomenon what it is and without which the phenomenon could not be what it is (2016). The qualities that make up the phenomenon of teaching science during the COVID-19 pandemic were universally experienced, broad-reaching in their impact and life-changing for all six teacher participants.

Ideal and nonideal theories play a significant role in the decision-making process the teacher participants' exercised according to their pedagogical judgment. The ideal and nonideal theory paradigm can be most significantly observed through the teacher participants' movement through the tripartite view of pedagogical judgment: pedagogical responsibility, pedagogical reasoning, and pedagogical action in negotiations to achieve a more favorable teaching scenario.

Chapter Structure

I separate Chapter 4 into two sections. The first section details each teacher participant's individual narrative according to their lived experience during the COVID-19 pandemic. I also highlight each teacher participants' pedagogical judgment according to the tripartite view: pedagogical reasoning, pedagogical responsibility, and pedagogical action (Horn, 2019). The purpose behind sharing each teacher participant's personal narrative was to provide an avenue for each participant's individual voice and experience. The extremely stressful events that unfolded during the pandemic garnered unique responses from each teacher participant.

The second section describes the essential themes and the shared narrative of the phenomenon, teaching secondary science during the COVID-19 pandemic. The teacher participants' pedagogical judgment is once again highlighted according to the tripartite view (Horn, 2019). The essential themes experienced by all the participants leads to a shared narrative, highlighting the essence of the lived experience for all six teacher participants.

When interpreting the central experience for each participant, Heidegger (1971) suggested employing the question "What was at the center of the event for this person?"

to elicit the essence of the phenomenon for each participant. By asking this question, I was looking at the whole picture of the experience for each individual participant. Through reading each participant's interview transcript five times through, from beginning to end, I was able to begin to interpret the experience of the phenomena for that individual (Heidegger, 1971).

After considering the whole experience of each individual, I wrote a journal entry detailing my personal views regarding the teacher participant's experience. This important step of the hermeneutic circle helped me formalize my pre-understandings of teaching during the pandemic. As a former science teacher and teacher educator, I recognized that I have an idea of what the science teachers experienced during the pandemic, but I did not live it. The task of reflecting on my pre-conceptions of the teachers' experiences aided in making my bias explicit, thus allowing space for new understandings of participants' experiences. Van Manen (2016) discussed in his book, *Researching Lived Experience,* the importance of reflection related to personal experience, because it is impossible to 'bracket' out the researcher's experience, as the researcher will find it constantly creeps back into our reflections. It is better to make my personal biases, pre-conceptions, assumptions, beliefs, and understandings explicit in order to make room for new understandings of the phenomena as experienced by the teacher participants.

Looking at the "whole," while also considering the individual "parts" of the experience, constitute the final step of the hermeneutic circle (van Manen, 2016). I describe the "parts" in the Essential Themes section of this chapter which were revealed through a highlighting of significant statements from each interview transcript. I then

grouped the significant statements together according to common ideas. I used the common ideas to develop essential themes that were experienced by all the participants. I also looked for data supporting the six essential themes in the lesson plans and Qualtrics surveys to contribute to a rich body of evidence. Phenomenological themes may be understood as the structures of experience. In exploring themes and insights, we can treat texts as sources of meaning (van Manen, 2016, pp.320). Weaving together the essential themes experienced by all six participants formed the shared narrative of the central phenomenon. The central phenomenon addresses the research questions for my study:

1. What does the lived experience of science teachers during the pandemic tell us about pedagogical judgment during the pandemic and pedagogical judgment in general?
2. How do science teachers navigate their pedagogical judgment in relation to ambitious and equitable teaching?

Individual Narratives

I uncovered an interpretation of each teacher participant's central experience while using the hermeneutic circle to revisit each participant's interview transcript. This practice of the hermeneutic circle helped me arrive at new understandings of the COVID-19 pandemic and teaching science through the participants' eyes. The holistic interpretation of a participants' experiences is one of the reasons I chose phenomenology over other qualitative methods. Phenomenology aims to develop insightful descriptions of the way a participant experienced the world pre-reflectively, without classifying, or abstracting it (van Manen, 2016). In order to develop a holistic description of the

experience for each participant, I asked, “What was the center of the event for this person?”

Here, I present the individual narratives of the six science teacher participants:

Anna: Building Relationships while Social Distancing

Anna is a science teacher at a public high school in the Midwest. She has been teaching for 11 years; during the pandemic she taught Honors and Advanced Placement courses. Anna focused very heavily on relationships and the social-emotional learning of her students during the pandemic. In all of her sample lesson plans, she strongly emphasized the need to “see” each student during remote synchronous learning and how she made an effort to check-in with every student individually (Appendix F). Anna mentioned in her semi-structured interview, one way she connected with her students was to provide individual recorded verbal notes to all her students:

> I think the other factor that came more into focus was social-emotional learning needs of students, by checking in more when we’re virtual. For example, sending voice memos and that sort of thing, just to help them feel connected to someone. I was cheering kids on, like just being a positive voice to them hopefully. I went to using all verbal responses when they turned stuff in on Google classroom. But I also think it is good for them to hear my voice and hear me say their name while we were virtual and just trying to connect in that way.

Anna said that she was emotionally and physically exhausted more than ever before during the pandemic. She attributed this to the need to connect with her students, which took more effort in an online environment and also while in-person but socially distanced

and masked. Building relationships is a salient factor in Anna's teaching pedagogy. Anna holds a strong pedagogical responsibility to build relationships and check-in with her students. She exercised her pedagogical reasoning in determining the mental and emotional exhaustion was worth the effort to integrate social-emotional learning into her interactions with students.

Ray: Planning During the Pandemic was Challenging Due to Uncertainty

Ray taught at two different public high schools during the COVID-19 pandemic in the Mountain West. As a result of changing schools, he taught a wide range of sciences including, chemistry, physics, biology, and earth sciences. Ray considered his student teaching experience his first year of teaching then his second- and third-years teaching were during the height of the pandemic. He is no longer in the education field, he says, as a result of the stress of teaching during the pandemic. Ray expressed his central experience quite succinctly with the word *uncertainty*. He frequently used this word to describe his experience. There was uncertainty with when school would return (if ever) to in-person learning, uncertainty in regard to schedules, and uncertainty in how to plan lessons because the mode of delivery would change from remote, to hybrid, or in-person.

The lesson plans he provided varied greatly in detail, with one lesson plan providing four pages of extremely descriptive plans and another lesson plan vaguely describing the plan for the day in a ½-page description (Appendix F). These lesson plans point to the ever-changing expectations placed on Ray during the height of the pandemic, which only contributed to the uncertainty of the situation. There was also uncertainty with how to take attendance, what factors to consider when counting a student present, how to

implement and facilitate labs, and what sort of schedule the school would be following that day:

> What I think was the biggest thing that affected teaching, and not only teaching but the students as well, is not knowing what is going on. Because I am a professional, who is there to get paid and often I don't know what is going on. I'm just waiting to be told what to do. Just amplify that by however much because you're 14, 15, 16 years old and they're like, "wait, am I supposed to be online?" and "do I take two weeks off or three weeks off?" That level of uncertainty…I changed between those modes from fully in-person to fully virtual to hybrid to fully virtual because of an outbreak 11 times. So to that level, you can't plan. Then kids just throw their hands up and are like "screw it." So I think the word ***UNCERTAINTY*** in bold, underline, italics, set it in a new font, as the overarching cross-cutting concept of all the pandemic stuff, that is the one word for me that was the biggest. Then there all the small challenges that go with that. But uncertainty is the biggest because it affects everything else… it's the domino effect. I mean it just kept going and going.

One of the most influential factors in Ray's decision to leave the education field at the end of two years was the constant changing of administration's expectations, whether it was lesson delivery method, lesson plan format, or a specific science course taught. The effort and time he put into providing quality science learning experiences for his students, in an extremely tumultuous environment, was not equal to the support or compensation he received.

Ray's teaching pedagogy strongly focuses on being prepared and planning for a multitude of possibilities. The chaotic conditions during the height of the COVID-19 pandemic made planning extremely difficult for Ray. He held a pedagogical responsibility to plan and provide rigorous lessons but the ever-changing situations around the pandemic made him feel like his efforts were not worth the time. The reconciling of providing quality lessons and the lack of time and predictability in teaching ultimately lead to Ray leaving public education.

Carol: Learning New Technology while Teaching in New Ways

Carol is a science teacher at a private school in New England. She has been teaching high school science for 28 years. During the semi-structured interview, Carol focused largely on technology use in the classroom. She expressed the feeling that she needed to be perfect when piloting technology resources with her students. Each question in the interview brought up examples of technology use for her. She even stated twice, "I know you would like pedagogical examples here but honestly technology implementation was at the forefront of my experience teaching during the COVID-19 pandemic." Carol discusses how new technology was introduced to faculty and her internal angst with the implementation of the new technology in the classroom:

> I would say in terms of difficulty — this is way too obvious — but just learning to manage all the new technology. So we came back to school in the Fall, and they brought us back earlier to try and learn the technology. Everybody got a new laptop. Everybody got an external microphone and new external monitor and webcam. We had to learn how to make all this stuff work together. You can't really test it out until you have the kids in

> the room and remote, so you can try some and test it out. But it's not the same, needless to say there was some angst, because we came back feeling like, I have to be perfect right? I have to start class on time. Every student has to be able to see and hear everything. I have to cover all the material that I would have covered even without all this craziness. It was like that; it was just nuts.

The use of webcams and document cameras were instrumental in teaching science at her school because of the large population of students residing in China[4] during the pandemic. While virtual teaching, Carol would often be at school alone with a webcam and document camera conducting experiments for her students to observe. Carol holds a pedagogical responsibility to ensure that all her students are able to participate, in some way, during experiments. Her pedagogical action meant that, during the height of the pandemic, she was often at school late utilizing technology resources to film and narrate experiments for student access.

Seth: Feeling Out-of-Control Even While Providing Rigorous Instruction

Seth was teaching 9th grade science during the pandemic at a public school on the East Coast. He has been teaching for 17 years and completed his Ed.D. in curriculum and instruction in 2017. Seth expressed feeling out-of-control often in his interview responses. The curriculum was out-of-his-control at the start of the pandemic when he was required to teach lessons his district's Office of Teaching and Learning (OTL)

[4] The private school Carol teaches at has a large population of foreign exchange students from China. During the height of the COVID-19 pandemic the students from China were not permitted in the United States due to federal policies. As a result, the students from China participated in class remotely for the entire 2020-2021 school year.

provided. “It was a roller-coaster of emotions and experiences during the pandemic. Some of it was out of our control, because we were told, this is what you have to do.” He also mentioned that when the school district transitioned to hybrid learning he felt as though none of his students were getting his full attention because his attention was spread between the online and in-person students. This was challenging because he could not provide a proficient learning environment for either group of students. Seth voiced his frustration due to the Office of Teaching and Learning dictating many the teacher moves throughout the pandemic — i.e. curriculum, collaboration with other teachers, schedule, classroom management techniques, testing, technology use, lab implementation and hands-on activities:

> Then in 2021-2022 they (administration) decided Zoom was too expensive and that as a district we would use Google Meets. So that was a whole another learning process for the teachers and students. So we had all these little changes. But Google classroom is still our main platform. The Google Meets was a 40-minute training in August before school started, like two days before the school year started, “these are your 45 minutes to learn this, and now you’re gonna do it.” We also learned Go Guardian[5], which is a way to monitor what students are doing online in your classroom. We had ParentSquare[6] and Defined Learning[7] for exploration. So we had three 45-minute presentations all in one day, two days before

[5] Go Guardian is software that helps schools manage a student’s online activity.

[6] Parentsquare is a mobile phone communication application used by schools.

[7] Defined Learning is an online library of standards-aligned interdisciplinary projects.

> school started and we were supposed to be ready to implement Google Meets. But it's funny because the Board of Education and our Office of Teaching and Learning in the Superintendent's office, they use Zoom. But we used Google Meets. One day they [OTL] had to join a Google Meet and they were saying, "this is harder, I don't know what I'm doing yet". But for the rest of us we were just thrown Google Meets and said, "it's the same thing (as Zoom)". But it's not the same thing.

Seth expressed feeling grateful for his experience teaching and learning prior to the pandemic while at a local university earning his Ed.D. in curriculum and instruction. That experience prepared him significantly for online teaching because most of his classes had an online component. But even with the familiarity of online class delivery, he mentioned feeling out of control during the events that unfolded during the pandemic.

Seth's pedagogical judgment focuses largely upon the ability to exercise his professional expertise related to curriculum and instruction. When the district OTL implemented changes, he felt as though his professional expertise and pedagogical action surrounding curriculum and instruction had been confined. This resulted in Seth feeling out of control. The previous experience teaching online at the local university provided a new avenue for creatively exercising his pedagogical action. The opportunity at the local university meant Seth developed new ways of thinking around curriculum and instruction. This allowed him to develop rigorous curriculum for remote and hybrid teaching at his school.

Sally: Keeping Students Accountable for their Learning During the Pandemic

Sally taught science for 11 years — four years in a homeschool co-op and seven years in a public school on the East Coast. Prior to the pandemic, she was nominated as one of the top 20 teachers in her county. After the 2020-2021 school year, she left the education field and pursued a career in industry, due to the stress of teaching during the COVID-19 pandemic.

Sally continually focused on accountability during the pandemic. She felt as though she had to hold the students accountable for quality work and that she was being held accountable by administration for making sure all her students passed her class. Part of this idea of accountability included her initiative to email parents of students who were missing work every Friday to keep the parents informed of what schoolwork their student was missing:

> The pandemic made it more challenging getting kids to work. Because they didn't want to do the work. At the end of the quarter, I would have 60-70% of my students with an F, which is crazy, in a normal year I might have two F's. But this was happening because there was no accountability. Parents don't realize how much teachers have to do on a daily basis to get kids to do the work when they're in class…So I started writing an email at the end of every week — it wasn't required of me, but it was my way to maintain some accountability. I would email the parents and tell them "Johnny hasn't turned in xyz" and I would give them a screenshot of

> Schoology[8] showing them everything that was missing. So depending on the kid and the situation, I would do that for the entire nine weeks.

The stress of constant accountability, starting with administration and trickling down to the students resulted in a teacher, who had just prior to the pandemic been nominated as a top teacher in her county, to leave the profession after 11 years.

Sally's pedagogical judgment surrounding student accountability was significantly challenged during the height of the pandemic. When students' performance expectations changed, the accountability also changed. This meant that Sally had to adjust her pedagogical action in new ways to continue keeping her students accountable for their attendance, participation, and schoolwork. The accountability became too much, and Sally chose to pursue a career outside of public education.

Bella: Building Bonds with Students and Sacrificing Mental Health

Bella taught middle school science at a public school in the Mountain West during the pandemic. She taught science for five years, three years in a non-traditional classroom and two years in a large urban district in the Mountain West region of the United States. After her two years in the large urban district, during the pandemic, she left the education profession.

Bella summed up the entire experience with the word *triage*. "We weren't doing genuine learning. Basically, I was a behavior manager and question answering facilitator in the classroom." Bella daily spent time teaching in-person students, online students, and students who had been quarantined for 2 weeks, all while managing middle school

[8] Schoology is a learning management system schools and teachers use.

behaviors that were magnified due to students' extreme social and emotional dysregulation as a result of the pandemic. Bella asked for support and guidance from administration several times during the pandemic, only to be met with the statement, "oh, you're just a new teacher." Additionally, she was regularly scolded publicly at staff meetings or passive-aggressively through an email, for her teacher choices and moves. This experience drove her to suicidal ideation because she felt as though she was giving her everything to the students and the educational experience, she was reaching out to administration for support and yet she was still told she wasn't teaching adequately from administration. Through it all, Bella still discussed her fondness and strong bonds with the students regardless of the adversity she continually experienced as a teacher:

> We survived it. I built some really strong relationships with kids, even though we faced a lot of adversity…I tried to take care of them "person first" as best I could…My success is, we survived, and I taught my kids some social-emotional skills and took care of them as best I could. They might have learned a little bit of science along the way.

Her use of the word triage in describing her pandemic teaching experience was profound, especially in the following excerpt from her semi-structured interview:

> Then I taught last year, when we were like, "Oh it's fine, it's all normal, we're going to quarantine kids that are within a 6-foot radius of a kid that gets COVID, it's fine and we're not going to require masks, it's fine, but don't forget to spray down your door handle." Remember when they said they were going to add good ventilation and cleaning procedures? They

> did not. I was in a classroom with no windows, none…Half the time we were all teaching in the freaking desert because the air conditioning was broken. We were teaching in 100-plus degree weather, with no AC, with 30-plus kids crammed into a classroom with no windows, no cross-breeze to speak of, in masks trying to teach kids and push them academically rigorous stuff and follow all of the state department's turnaround needs, it's disgusting.

The urgency of meeting strict state performance and assessment benchmarks, even throughout the pandemic, led to a feeling of being in a battle zone or in the aftermath of a large natural disaster. Her use of the word "triage" is telling in describing her lived experience during the pandemic.

Bella held a pedagogical responsibility to focus on relationships with students. Her response to teaching in a battle zone was to focus on relationships first, this pedagogical action was in contradiction to the priorities of the school she taught at. To reconcile the contradiction, Bella fortunately determined that her mental health was important and left teaching (for now).

Individual Narrative Summary

Each of the six teacher participants I interviewed, all experienced teaching science during the COVID-19 pandemic, yet each had profoundly different lived experiences. Anna and Bella worked to build relationships with their students, while also managing their own mental health. Anna managed her mental health by moving in with her parents in order to share the household obligations and childcare. Bella adopted a cat to provide companionship and comfort due to the extreme isolation she experienced from the

pandemic. Carol and Seth focused on new technology and effective implementation. Carol found success implementing complicated technological resources and continues implementing the resources currently in her classroom. Seth leaned into his past experience remote teaching at the college level to provide rigorous instruction. Sally strived to keep students accountable for their learning and developed methods for communicating with parents effectively while working remotely. This resulted in a majority of Sally's students successfully completing her class. Ray worked hard to be ahead of the constant changes the pandemic brought him and even developed step-by-step plans for his colleagues to follow when developing lessons for remote teaching.

Van Manen (2016) describes the essence of the experience, not as a single fixed property, but a complex array of aspects, properties, and qualities. These six participants approached their response to teaching during the pandemic in vastly different ways and their responses yielded widely varied teaching experiences. Though the complexity of the experiences lived by the six teacher participants is widely varied, there were six themes that were common amongst all the participants. I share the essential themes found within all the teacher interviews in the next section.

Essential Themes

Following the hermeneutic phenomenology tradition, I uncover the individual parts, or themes, by highlighting significant statements in the interviews and looking for any commonality of ideas amongst the interviews. Excerpts from the Qualtrics survey and participant-provided lesson plans further supported the findings for the six themes. I present each of the essential themes through a lens of pedagogical judgment, to address my research questions:

1. What does the lived experience of science teachers during the pandemic tell us about pedagogical judgment during the pandemic and pedagogical judgment in general?
2. How do science teachers navigate their pedagogical judgment in relation to ambitious and equitable teaching?

To answer the first research question, I identified four themes: (1) First Impressions of the Pandemic, (2) Confusion of the Pandemic, (3) A New Normal, and (4) Technology as Aid and Hinderance. These themes focus on the lived experience of the teacher participants. All six participants experienced situations contributing to the four essential themes above. To answer the second research question, I identified two additional themes: (5) Thoughts on Equity, and (6) Facilitating Ambitious Science Teaching. These themes specifically address the concepts central to my research: ambitious science teaching, looking at scientific inquiry specifically, and equity in teaching.

First Impressions of the Pandemic

From the very beginning of data collection, I found that participants were very eager to share their initial thoughts and experiences of teaching science during the pandemic. The interview question, "Tell me about your overall experience teaching during the pandemic" elicited strong responses from all six participants. These first impressions occurred during March of 2020 when the entire world began social distancing and stay-at-home orders began for many states in the U.S. All six participants discussed the type of instructional delivery and the duration. Some teacher participants' schools completely closed and other teacher participants' schools immediately began remote learning via Zoom. Ray's school completely shut-down:

> …from the very moment that they shut my school down for the pandemic. At first it was for 2 weeks, then 3 weeks, then through spring break, then we'll do one month online, and we'll be back at the start of May.

Whereas Sally's school began synchronous learning on day one, "So everybody goes home, and they send the teachers information, and basically for 4th quarter at our school we met through Zoom."

Each teacher described their initial response to the pandemic quite strongly. The initial descriptions — *challenging*, *unknown*, *uncertain*, *stressful*, and *crazy* — point to a season of tumultuous changes for the teachers. Several teacher participants expressed their feelings through questions like, "What is going to happen?" and "What does this mean?" The pedagogical actions related to the teacher's first impressions of the pandemic show that the teachers were charting an unknown path. The *challenging*, *unknown*, *uncertain*, *stressful*, and *crazy* descriptors provide insight into the teacher's thought process. For most there weren't any plans for such a disruptive event. The fact that the teacher participants did not have plans for such a large upheaval to the status quo, reveals pedagogically that such a tumultuous event had possibly not even been considered or teachers might not have been provided time to plan for such an event. The pedagogical judgment the teacher participants exercised at the beginning of the pandemic reveal that March 2020 was largely unexpected.

Confusion of the Pandemic

Once teachers had somewhat settled into the first few months[9] of teaching during the pandemic, confusion about implementation of science concepts and how to handle situations provided new challenges related to the pedagogical judgment teachers made. May and June of 2020 brought new complexity to the remote classroom that continued into the beginning of the 2020-2021 school year. Many of the teacher participants taught in a hybrid format, meaning some students were in-person at school and some students were virtual at-home. This required the teacher participants to be present simultaneously in the two formats: in-person and virtually. For example, Bella expressed her frustration with multiple instructional delivery methods being conducted simultaneously:

> I was expected to run an online Zoom or Google meet and teach kids on the screen, while also teaching kids in the classroom the same concept all from the computer. So I was supposed to answer questions for kids online in my Google Meets, while also handling the behaviors and questions in my physical classroom. I will never do that again. I absolutely refuse, because it was the most stressful thing I have ever done in my life.

Similarly, Seth expressed his frustration with hybrid teaching:

> My grandfather asked me what it was like. I told him, nobody gets my full attention. Because I can't give my attention to the kids in the classroom because then the students on Zoom don't get it. If I give my attention to the students on Zoom, then the students in the classroom don't get it. So

[9] The first few months of the Pandemic refers to March and April of 2020.

> hybrid was slightly better because we could see and interact with the kids. But you were still splitting your attention, so I felt like I couldn't do justice to either group of kids.

Multiple modes of simultaneous lesson delivery were a common aspect of teaching for all six teacher participants. None of the teacher participants enjoyed this form of lesson delivery or found this method of teaching effective.

In the above scenarios, the teachers' pedagogical actions were constrained. They were instructed 'how' they must deliver science instruction. The delivery mandate created conflicts internally for the teacher participants. Both Bella and Seth held a pedagogical responsibility to provide quality science instruction where the students received the attention they needed, yet that was not possible given the hybrid teaching format the teacher participants were required to facilitate. Even though Bella could not change the teaching format, she exercised her pedagogical judgment to facilitate lessons with concepts the students could use in their daily lives. This took the form of embedding social-emotional concepts into her lessons and providing numerous ways for students to show their understanding of a concept. Seth reconciled his limited pedagogical action by utilizing his pedagogical reasoning to integrate ways for remote and in-person students to interact during a lesson. Both Bella and Seth used their pedagogical judgment to develop innovative ways to engage their students while reconciling their lack of pedagogical action in lesson delivery method.

Without being able to predict the format of lesson delivery — Would students be in person? Would the entire class transition to Zoom because of a COVID exposure? Would some students be quarantined, but not others? — teachers found it challenging to plan

lessons. This is evident in the lesson plans the teacher participants provided; the lessons do not precisely describe the *how* of lesson delivery, as this often would change last minute due to COVID-19 outbreaks. Planning a lesson for a typical hybrid day for Ray required multiple new considerations:

> All the virtual things, as a teacher, had to be independently doable. So B cohort[10] had to be able to do it without coming to class and A cohort had to do it after being in class. So it couldn't be too low-ball so that they (the students) didn't burn through it. It had to be useful, but also able to be done independently." The multifaceted requirements for hybrid teaching stretched Ray's thinking of science and lesson facilitation beyond any experience prior.

Even attendance, a seemingly simple task, became complicated. Sally relayed her frustrations with attendance and the limited expectations for students around attending class:

> In order to count as 'in attendance' that day, students had to log-in and do the warm-up, but they had 24 hours to submit the warm-up. So as long as they logged in and did the warm-up, they were counted present for the day, even if they didn't do the work. I had students who would log in, turn on their cameras for a split second, and because they turned on their camera for those 30 seconds, that counted as their attendance for the day,

[10] A and B cohorts refers to groupings of students. At Ray's school, administration placed students in a cohort and students attended school with only their cohort to minimize the number of students in-person at school at any one time. Placing students in cohorts was done to hopefully reduce COVID-19 transmission and the number of students affected.

even though they didn't submit my warm-up. Because they logged in and showed their face they were counted in attendance.

The confusion around teaching delivery method, lesson planning requirements, and attendance required new ways of thinking about teaching for the teacher participants. Instructional delivery during the pandemic was different and more complicated than any participant had experienced before. Lesson planning required considering new ways of facilitating class and introducing science concepts. Even attendance stretched the teacher participant's former ways of thinking.

In each of these scenarios, teachers were required to exercise new ways of thinking around their pedagogical responsibilities. When the agency of lesson delivery had been removed, Bella and Seth exercised their pedagogical reasoning in other areas of lesson delivery. If the mode of delivery was uncertain, Ray found creative ways to lesson plan and still account for possible last-minute changes. Sally didn't agree with the new attendance requirements but continued to follow the confusing guidelines. Each of these teacher participants were presented with requirements that did not support their pedagogical responsibilities, yet each participant exercised their judgment in how to move forward in a manner that was still productive.

New Normal

After the initial shock of the pandemic in March of 2020 and the confusion of how to carry on in the preceding months, the summer of 2020 allowed teachers a little bit of prepping time for a 'New Normal' at the start of the 2020-2021 school year. Teachers found themselves planning for minimal participation from students. New requirements for lesson planning and facilitation added another layer of complexity for many of the

teacher participants. Masks were an added factor and seating charts became one of the most important requirements for teachers.

Student Participation

Four of the teacher participants mentioned extremely low class attendance during the pandemic. With some participants even mentioning there were students they never even saw for the entire grading period. Bella described her class attendance, “Kids didn’t show up. I had maybe two or three kids show up for each class, and so participation took a total nosedive because kids were mostly home alone, because their parents work (shocker).” Sally also mentioned some frustration around student attendance:

> Then COVID hit and you’re lucky to have 5 kids login to a class, so I can’t really separate students into groups, and I can’t guarantee students will be able to work together outside of class and I didn’t want one kid to do all the work.

Sally brings up some important factors that brought some angst when planning during the pandemic, “How do you group students?” and “Will students be able to work together outside of class?” These pedagogical responsibilities required new ways of thinking about teaching. The lesson plans the teacher participants provided show evidence of new ways of thinking about lessons and facilitation, with options in how to complete the work and collaborate with peers (Appendix F).

Teachers’ lesson plans also show a change in lesson accessibility due to student attendance. Some lessons were virtual and synchronous, using webcams for students to follow along; other plans were pre-recorded and made available for students on a class page website for individual viewing when the student had time. Overall, the lesson plans

show a dramatic shift in how teachers were thinking about lesson planning, whether it was extremely flexible student groups or the type of delivery, the lesson plans point to a new normal.

New Administrative Protocols

Additionally, teacher participants discussed new requirements to lesson plan and facilitate science lessons with colleagues. This meant administration required teacher participants to develop all of their lesson plans with their colleagues and facilitate the same lesson plan on the same day as their colleagues. Seth stated the new requirements made him anxious:

> They wanted us (the 9th grade science team) to be much more homogenized. The whole team was supposed to plan together, using the same lesson. So now everybody is doing the same thing. But there are four of us and we have four completely different personalities…So we all have different personalities and different interests and different ways of going about teaching and what suits us. We all have different kids in front of us. So I think it is OK to plan in a more broad sense together. But when it gets down to, this activity here this day and we should be at this point on this day, that sort of thing makes me anxious, just trying to keep more of a focus on the pacing guide because of the learning loss.

The requirement to plan and teach in exactly the same manner as colleagues limited the opportunity for pedagogical reasoning. This can make a teacher constrained in their pedagogical action rather than integrating elements according to their expertise and pedagogical judgment.

Health and Safety

Masks were a hotly debated topic during the pandemic. All the teacher participants lamented having to enforce students' compliance with mask wearing. The teachers felt as though this was one more thing they needed to pay attention to. Masks also inhibited communication. Anna found that her teaching style needed revision due to mask wearing:

> But I feel like there was a real loss of emotional connection, which is one of my strengths as a teacher. Presenting material in an engaging way, just telling stories along with content. You know it is harder to joke with kids because they couldn't see your face, and if you were smiling...So I felt like I had to teach much more with my whole body, so I was more tired because I was doing way more hand movements and moving around to keep the kids engaged, because my face wasn't shown.

Along with the loss of emotional connection and the added classroom management task of making sure every student was wearing their mask correctly, teachers were fearful of discussing the need for wearing masks. Many of the communities the teachers taught in had parents protesting mask wearing in schools. This meant teachers were afraid to discuss the science behind disease transmission and mask wearing. What could have been a powerful teaching moment was lost through fear of backlash from the community.

Ultimately, the teacher participants were at a crossroads concerning their pedagogical responsibility of utilizing teachable moments to educate their students about COVID-19 transmission and maintaining peace and harmony with the community out of fear of backlash around a controversial topic. The conflicting pedagogical responsibilities the teachers faced show the complex dynamics of a typical day teaching during the

pandemic. In an ideal scenario the teachers would seize the opportunity of a teachable moment, but the very fragile and volatile atmosphere surrounding the COVID-19 pandemic meant that teachers often chose to not discuss the science behind masks in order to keep their jobs and prevent discord amongst the community.

Seating charts, pre-pandemic a mundane activity, became one of the most important elements of teaching during the COVID-19 pandemic due to the need to conduct contact tracing. This introduced new challenges for teachers, like Bella:

> Seating charts, I hate them, they're such a waste of time. We needed to submit seating charts, they had to be posted online in a place where administrators could see it. That way they could do contact tracing for Covid outbreaks. So you had to stick to a very specific seating arrangement, and I couldn't do the classroom management technique of, "well I'm just going to move you over here". If I did that, I'd have to change the seating chart to reflect that because then when they (administration) did contact tracing for COVID-19 protocols, if you're within a 6-foot radius, it became important. So you had to maintain the same seating charts and couldn't use some of your management skills because they (administration) were like, "we need to know where every single child is at all times."

Developing new classroom management techniques takes time and practice. The loss of a technique can mean the loss of instructional time. For example, the students are being disruptive, and the teacher doesn't have the resources needed to minimize the disruption due to pandemic protocol changes. Beyond classroom management, the

seating chart requirement also meant students could not move around the classroom for labs, activities, or group work.

The pandemic meant a reworking of many standard teacher pedagogical actions during classroom facilitation, because suddenly students couldn't move around the classroom. For Bella this meant she focused heavily on relationship building and social-emotional learning. When one pedagogical action was no longer a possibility, (e.g., strategically grouping and placement of students), she focused on other pedagogical responsibilities that resulted in similar outcomes, (e.g., building relationships with students as a classroom management technique).

Technology as Aid and Hinderance

Technology was absolutely integral to K-12 education during the COVID-19 pandemic. All six teacher participants taught online in some form during the first two years of the pandemic. Yet, the teacher participants were not formally trained how use different technology resources. Every teacher participant discussed the need to teach themselves how to use technology resources integral to successful pandemic teaching. The self-teaching was always on the teacher participant's own time.

Some of the technology resources that were new to the teacher participants created quite a bit of angst around instructional implementation. Sally's first online synchronous lesson was completely taken over by the students:

> So the very first time I tried Zoom, I had 150 students on the roster, 90 of them actually showed up to class, though not all at once. I wasn't so familiar with the technology at the time and the kids had their mics on and I couldn't mute them. So the students were talking over the top of me and

> one boy figured out how to animate and write on the screen. So I'm sitting there talking and all of the sudden these words and symbols start showing up all over the screen, it was total chaos.

After the experience above, Sally spent hours familiarizing herself with the online platform prior to the next online class.

Interacting with students virtually also presented issues for many teachers. Students would not turn on their screens during synchronous learning for fear of peers viewing their home life. This made group discussions and any kind of interaction amongst students minimal, if it occurred at all.

Many students did not have a computer, reliable internet, or strong internet bandwidth. These students could not participate in class or complete schoolwork. Many school districts attempted to provide computers and internet access to students, but tracking down unhoused students or students who frequently moved posed a problem. Even when students were provided computers and internet access, many students still struggled with reliable sources to charge their computer or fast enough internet bandwidth to view a video. The teacher participants expressed large discrepancies around access to technology resources without much action taken by the school districts to remedy the inequities.

Beyond the angst of constantly changing technology and access to technology resources, there were some benefits to using technology during the pandemic. First, and most importantly, formal education might not have occurred during the pandemic if it wasn't for technology. Technology provided an avenue for students and teachers to meet virtually, rather than in-person and risking COVID-19 exposure. Teachers could facilitate

lessons virtually, while socially distanced at home and each student could join the virtual class from their own space. Students were able to continue learning in some fashion and stay connected to their teachers and peers through the use of technology resources. Most of the teacher participants recorded their online synchronous lessons and posted them on a private page for their class to view. This meant that students who missed the class could access the lesson at any time when it was convenient for them. Teacher participants also mentioned that they had pages online that contained resources for their students. Resources may have included supplemental material to further understanding of a science concept, videos of experiments, explanations of chemistry and physics equations, and additional examples of student work or science concepts.

Lastly, several teacher participants mentioned that online learning meant fewer distractions for students. This meant every student had a front row seat to the computer screen and could see everything that was happening. There weren't distractions from intercom announcements or peers getting up to go to the bathroom or sharpen a pencil. The reduction in class disruptions meant increased engagement from the students who did join class online.

Technology truly can be an asset to education and classroom instruction. The thoughtful implementation of technology makes it an asset for all; the lesson plans provided show a wide variety of technology resources (Appendix F). Technology can help teachers implement creative solutions by exercising pedagogical actions that may have not been available without technology resources. For example, teachers were able to conduct virtual experiments and labs, engage the students in scientific discourse via Zoom and Google Meets, and provide multiple online scaffolding tools for student

understanding. These pedagogical actions allowed students and teachers the opportunity to continue engaging in rigorous activities as they would have prior to the COVID-19 pandemic.

Ambitious and Equitable Science Teaching

The next two themes address the research question:

> 2. How do science teachers navigate their pedagogical judgment in relation to ambitious and equitable teaching?

I asked specific questions in the semi-structured interview and Qualtrics survey related to scientific inquiry and equitable teaching, as these concepts are central to the research I am conducting around science teachers' experience during the COVID-19 pandemic. These two essential themes were also evident in all of the teacher participants' provided lesson plans.

Thoughts on Equity

Each of the six teacher participants discussed equity frequently, even without the specific questions in the Qualtrics survey and semi-structured interview related to equitable teaching practices. The discussion of equity was so frequent in all six participant interviews that I consider equity a core pedagogical responsibility for all the teacher participants. While coding for themes, I broke down the broad theme of equity further, looking for specific ways equity was mentioned in the data. After placing all the significant statements related to equity together, I looked for commonalities. The two most common ideas every teacher mentioned regarding equity were relationships and access. Teachers were thinking about their relationships with students, and the students' relationships with each other. Access refers to the availability of learning materials and

opportunities for students during alternative lesson formats (i.e. virtual, hybrid, and in-person socially distanced). The teacher participants often found themselves thinking through their pedagogical responsibility, in trying to find ways for all of their students to have access to learning materials and opportunities.

Equity in Relationships

Relationships were at the forefront of the teacher participants' thinking when it came to pandemic science teaching. Each teacher shared their thought processes in relation to planning for teaching: "Am I interacting with all my students online?" "Am I reaching out to the students who are not very active in online class?" Anna shared that she recorded voice memos for every student regularly and made a point to say the student's name in the memo. She said it was important to her that the students heard her voice, especially during such an isolating time as the pandemic. Anna used her pedagogical reasoning to develop creative methods to connect with her students when the typical pedagogical action of talking with students in-person was not an option.

Carol organized her students into small groups on Microsoft Teams for online support. She would set up meetings with teams of students outside of class time to check in. In this way, individual students weren't isolated and also had access to peers for support. Bella encouraged online relationships amongst her students by teaching them how to interact in a positive manner:

> How do we collaborate virtually because we still wanted kids to have good conversations with each other? So we did a lot of discussion boards, and had to come up with guidelines around, "How do we respectfully communicate with each other digitally?" Which for students was huge

> because they love to cyberbully each other. It's easy for kids to be like, "you're wrong!" online. As teachers, we have to remind them, "No, no, no, you have to say, 'I disagree because…' The because is the important part; you can disagree respectfully and 'here's why I disagree...'" They got a little bit better at writing out their thoughts.

The pedagogical actions around developing and fostering positive interactions point to a teaching pedagogy focused on equity and relationships. The teacher participants could have taught during the pandemic in a 'business as usual' format, without extra effort in fostering relationships. But the extra time invested through voice memos, evening phone calls, and teaching students how to respectfully talk to each other provide evidence that relationships were a salient factor in the teacher participants' pedagogical responsibility.

Equitable Access

Access went far beyond access to technology. The teacher participants were concerned about access to learning materials and access to equitable learning opportunities. The access to learning materials was incredibly challenging during the COVID-19 pandemic. The teachers mentioned access to content as a concern in both the Qualtrics survey and their interviews. This often took form through 'choices.' Students were given a plethora of learning materials, including interactive websites, videos, personal classroom pages, online worksheets, and google forms. Students had the opportunity to choose which resources worked best for their learning needs. The teacher participants embedded interactive readers on slides and videos for students and provided readings in multiple literacy levels for English language learners. All the teacher

participants took steps in order to ensure their students had access to numerous resources online.

Quarantining and isolation due to illness were daily considerations related to equitable access to learning opportunities. Teacher participants used their pedagogical action to design new ways for students to access learning opportunities. Anna provided 'conclusion binders' for students because the school's curriculum was heavily discussion based:

> A big struggle we had this past year and the year before was kids getting quarantined and being out for 2 weeks. How do we present material to them equitably? So I feel like this 'Open Sided' unit we're constantly looking at the standards and discussing and concluding. It was really hard to have the students do this on their own, because they weren't there for the discussions. So we had a binder and had the students write down things in class "this is our conclusion". In our slides in teacher notes we put in very specific directions for them. It was a big struggle.

Seth recorded videos of labs conducted at school, posted them on the classroom website and required remote students to extrapolate what would occur in the lab based on what they observed:

> So remote students could still participate. They weren't taking the measurements and they might not have seen the activity first-hand, but they could still see the process and the data and make a connection as to what would happen. So the students that were in class did the activity and those students who were fully remote could still watch the video and get

the data and have an experience somewhat similar… So we tried to compensate the best way we could.

Though the learning experience was different for students in-person and students online, teacher participants took steps to ensure the learning occurred in the most equitable manner possible.

Summary of Thoughts on Equity

The pedagogical judgment teacher participants exercised during the extremely disruptive events around the pandemic show that equity was a continual practice and process. This meant being creative in new ways to develop and maintain relationships with students. Teacher participants had to be inventive when providing equitable learning opportunities for students due to differing modes of delivery. Each teacher participant held a personal pedagogical responsibility to pursue equitable teaching practices as evident throughout the Qualtrics surveys, interviews, and lesson plans. Practices that foster an equitable learning environment were present and integrated in meaningful ways.

Facilitating Ambitious Science Teaching

Ambitious science teaching, looking specifically at scientific inquiry, during the pandemic required a new way of thinking about teaching. Most of the teacher participants stated that they did not do any sort of hands-on experiments. But this did not mean scientific inquiry, or any type of ambitious science teaching did not occur. Ambitious science teaching includes practices such as inquiry, analyzing data, scientific reasoning, and data-based discussions. I focused most of my research on inquiry but throughout the data collection and analysis process it became evident that teachers were enacting some of the other ambitious science practices that were incredibly relevant to my research.

Each of the teacher participants brainstormed new ways to facilitate scientific inquiry and other practices of ambitious science teaching. For example, Anna describes some ambitious science practices that she focused on with her students:

> In my opinion, it's more about, "How do you think?" "How do you problem solve?" "Can you read a graph?" Because you are seeing a lot of graphs, and can you tell if it is misinformation? I think those are the skills that moved up in importance for me.

The discrete practices of analyzing and reasoning were an important part of Anna's pedagogical responsibility. She had been hesitant to do labs while teaching remotely because she wasn't sure what supplies students had at home and didn't want to embarrass students who might not have the supplies they needed. While using her pedagogical reasoning, Anna creatively modified a mutualism experiment for students to engage in while learning remotely:

> At the end of the school year in 2020 we were in ecology, which was perfect. I was making activities just to get the kids outside. 'You need to go outside and find mutualistic[11] relationships and send them to me.'

Bella also focused on ambitious science teaching and utilized her pedagogical reasoning to develop an experiment about light that could be completed at home with almost any sort of supplies:

> One of our more successful ones was a light experiment that we built where they basically were like, take something that makes light, whether

[11] Mutualistic Relationship is a type of symbiotic relationship where all species involved benefit from the interaction.

> it's your phone, a flashlight, whatever and see how it moves through different substances. "How does it move through glass?" "How does it move through water?" "How does it move through a wall?" They had to build their own experiment to demonstrate the different ways that light moves, so refraction, reflection, absorption, scatter that kind of stuff. They had to apply the technical terminology to their findings. There was no one right answer. They just had to design a quick experiment, and then they wrote a CEA (claim, evidence, analysis).

This activity required students to problem solve, be creative and apply scientific reasoning to conduct an experiment and write a CEA. The activity could be completed almost anywhere with anything and yet was rigorous and allowed for students' autonomy in how they chose to conduct it.

Seth focused heavily on scientific reasoning during the pandemic. When teaching in a hybrid model he found ways to engage students in inquiry:

> There is one — redshift during the Big Bang — where you put dots on a balloon, and you inflate the balloon to see which dots move away from each other faster. We did that one. We had air pumps in the classroom, so everybody didn't have to use their mouth, cause we had to keep our masks on. If somebody had a balloon at home, they could have still done that activity. But if they didn't, we had a YouTube video that showed the activity, then we gave them the data table at the end.

In this activity, Seth took pedagogical action to ensure each student had access to the data table, so each student could engage in scientific reasoning. The hands-on activity was

beneficial, but not necessary for ambitious science teaching to occur. Students who were remote could still observe the redshift concept by video, but it was the manipulation of data in the data table that reinforced ambitious science practices such as analyzing and reasoning.

Sally used online simulations to encourage scientific inquiry. She encouraged the students to figure out how something worked in the simulation through experimentation. This meant allowing the students time to manipulate the variables in the simulation. Ray shared videos of experiments with his students and engaged the students in online scientific discussions about the science concepts displayed in the video. Carol had document cameras and would record herself conducting experiments. During hybrid learning, students in-person had access to document cameras, and they would conduct an experiment while remote students were observing. Sally, Ray, and Carol all used their pedagogical action to provide ambitious science opportunities for their students.

Each teacher participant found ways to creatively integrate different aspects of ambitious science teaching, even while considering the many constraints COVID-19 placed on teaching and learning. The pedagogical judgment these teachers exercised in order to provide a rigorous learning environment for their students relays the importance of ambitious science teaching and scientific inquiry specifically. Each teacher participant found creative ways to engage their pedagogical judgment to provide the tenets of ambitious science teaching, even in midst an extremely tumultuous event, such as a pandemic.

Shared Narrative

Through the hermeneutic phenomenological process, I have circled back and am arriving at a new understanding of the phenomenon of teaching science during the COVID-19 pandemic. The goal was to illuminate the essence of the phenomenon without embedding my personal bias. I achieve this through the hermeneutic circle. The parts (essential themes) inform the whole, and the whole shared narrative, inform the parts (essential themes) (Peoples, 2020). While digging deep into the six essential themes of the phenomenon a shared narrative of the lived experience of science teachers emerged.

The initial impressions of the pandemic were largely based on not knowing what the future held. Each teacher participant expressed their initial impressions of the pandemic with descriptive words: craziness, uncertainty, unknown, challenging, and stressful. Since no one had experienced or prepared for such an event, confusion ensued. The teacher participants shared the varying expectations of administration, and districts. It was incredibly challenging to teach in three different delivery modes while simultaneously managing classroom behavior. This stretched the teacher participants' pedagogical judgment in new ways. Even attendance protocols varied widely, making a 2-minute pre-pandemic task sometimes take over 24 hours to complete.

Eventually, teachers began to adjust and make accommodations for the 'new normal' of student participation, administrative protocols and health and safety. Most of the teacher participants lamented the extremely reduced number of students who participated in class during remote teaching. This meant rethinking pre-pandemic pedagogical judgment concerning group work and class discussions. While hybrid teaching, seating charts and masks became regular features in the classroom, enforcement of mask wearing, and contact tracing often took precedence. The use of technology became

central to the pandemic classroom. Teachers had little support in learning how to use different technological resources and typically needed to teach themselves how to use the resource. Whether it was remote, hybrid or in-person teaching, teachers used some form of technology to optimize the learning experience for students.

Equity was important to all the teacher participants and was most commonly operationalized through relationships and access to resources. Teacher participants found new and creative ways to enact their pedagogical judgment to connect with their students virtually. The equitable access of educational materials and learning experiences for students meant teachers provided numerous choices in learning, even during the tumultuous circumstances of the pandemic, to meet the varying needs of students. Ambitious science teaching may have looked significantly different during the pandemic, but formative practices of AST were still present. Teacher participants found ways to conduct inquiry without a hands-on component. Scientific reasoning and analyzing data were still at the forefront of a lesson. Clearly, the teachers who participated in this study are resilient, they developed innovative methods to enact their pedagogical judgment during such a chaotic time in education. They faced one of the biggest disruptions to education that we have experienced this century, overcame adversity, and still focused on equity for their students and ambitious science teaching for a rigorous learning environment.

The pedagogical responsibility these teacher participants held towards ambitious science teaching, and equitable teaching practices is remarkable. Even during the constantly changing educational environment, the teacher participants reworked their teaching, found alternative ways to implement scientific inquiry and other elements of

ambitious science teaching, and creatively fostered positive relationships with students. When administration decided hands-on activities and close contact with other people were not safe, these science teachers exercised their pedagogical judgment to find new ways to cultivate a rigorous learning environment.

Summary

In summary, the individual narratives section of Chapter 4 details the central experience for each teacher participant. I interpreted this central experience by asking, "What was the center of the event for this person?", while analyzing the semi-structured interview of each participant (Heidegger, 1971). In the essential themes section, I discuss the six themes that emerged during analysis of the teacher participant interviews. Each theme is viewed through the lens of the teacher's pedagogical judgment which highlights the ideal/nonideal theory paradigm the teacher participants worked through. Excerpts from the Qualtrics survey and lesson plans also support the six themes that emerged during analysis. Lastly, I generated a shared narrative of the phenomenon, teaching secondary science during the COVID-19 pandemic.

Reporting the phenomenological data I collected for this research study on science teachers' lived experience during the COVID-19 pandemic was an ethical endeavor. My goal was to accurately represent each participant's lived experience with integrity. I felt strongly that science teachers needed an opportunity to voice their experiences teaching during the height of the COVID-19 pandemic. Each participant generously shared their time and experience with me. Their reality during the unfolding of events of the pandemic reveal their thought processes and priorities through their mind's eye. My job was to communicate and interpret that reality for future use in education. The individual

narratives reveal each participant's central experience. The six essential themes are common amongst all the teacher participants and are woven together to create a shared narrative. The shared narrative provides insight into a reality lived by science teachers in the U.S. Now that reality can serve as a guide for action steps in preparation for future extremely tumultuous events that disrupt education in the United States. In Chapter 5, I present my conclusions and future directions for research in this field based on my research study's findings.

Chapter Five: Reflections, Conclusions, & Implications

Chapter 5 begins with a brief review of the research findings from Chapter 4 in order to situate the findings within the review of literature. Next, I synthesize the research findings and discuss how the study addresses the research questions, while also tying the findings to the current literature. I will also weave in connections to the theoretical framework pertaining to pedagogical judgment, ideal/non-ideal theories, and hermeneutic phenomenology. Finally, I will share implications of the research and recommendations for future research.

Review of Research Findings

The purpose of this research was to give voice to secondary science teachers and their experience teaching during the COVID-19 pandemic. While I cannot generalize this research study for all secondary science teachers in the United States it does provide an in-depth view of six science teachers' experiences. The purpose of hermeneutic phenomenology is to gain insight into the way the world is experienced through the participant's eyes pre-reflectively, without classifying it (van Manen, 2016). My goal in utilizing hermeneutic phenomenology was to provide the reader with a holistic and descriptive view of the complexity of experiences science teachers faced regularly during the COVID-19 pandemic.

In my research, all 6 participants were required by their administration to deliver science instruction per the district's discretion (remote, hybrid, or in-person).

This meant that the teacher participants' pedagogical actions were constrained. As a result, the teacher participants found alternative ways to integrate ambitious and equitable science practices into daily lessons and interactions with students.

All six teacher participants mentioned equity as a salient factor in science instruction delivery and in their pedagogical responsibility. Even though lesson delivery had been decided by administration, the teacher participants provided equitable access to science instruction by recording all of their lessons and posting their recorded lessons on webpages for their students to access at any time. Three teacher participants additionally made themselves available via phone or Zoom calls during the evening and weekends for students needing further explanation of science concepts. The teacher participants exercised their pedagogical judgment related to equitable access of science by creatively thinking of new ways to make science accessible beyond their administrations' mandated form of delivery.

The teacher participants creatively found ways to facilitate ambitious science elements during the COVID-19 pandemic. Five of the teacher participants mentioned that their school district did not allow hands-on experiments during virtual learning due to safety and accessibility concerns for students. This meant the teachers used their pedagogical reasoning to implement modified scientific inquiry. The concepts of ambitious science teaching most often enacted were hands-on activity alongside scientific discourse, student knowledge generation and data driven explanations. All six of the teacher participants exercised their pedagogical judgment in determining that the elements of ambitious science teaching were important enough, even given the extreme

conditions of the pandemic, that the teacher participants found new and innovative ways to implement ambitious science.

Research Results through the Theoretical Framework

The theoretical framework for my research focuses on hermeneutic phenomenology, pedagogical judgment, and ideal/non-ideal theories. I explored the phenomenon of teaching science during the COVID-19 pandemic through this framework. Hermeneutic phenomenology allowed me the opportunity to dig deep into the varying elements of each science teachers' experience. My goal in using hermeneutic phenomenology was to present a detailed description of the complex pedagogical decision-making teachers made related to classroom instruction during a tumultuous and ever-changing environment. While contemplating ideal and non-ideal theories through the context of the COVID-19 pandemic, each science teacher's experience was viewed through a lens of *ideal* and lived or *less than ideal*. A state of *less than ideal* was not bad or undesirable, it just meant the elements of human nature and the unpredictability of the COVID-19 pandemic were significant factors in the implementation of ambitious and equitable science teaching.

In a favorable scenario, each science teacher would have the opportunity to conduct scientific inquiry remotely and each student would have access to all the technology, space, support, and supplies needed to participate in scientific inquiry remotely. Though this did not happen in the lived experience, each science teacher exercised their pedagogical judgment and found alternative methods for increasing access to resources and innovative ways to facilitate scientific inquiry remotely. The semi-structured interview process I employed during data collection allowed me the space to gather intricate details of a teacher's thought processes and decisions (Billups, 2021; Creswell,

2018). This allowed me the opportunity to ask a teacher participant for further details about why/how they decided to facilitate a class in the manner they chose. Gaining access to science teachers' thought processes provided me with a pathway through their individual navigation of the ideal/non-ideal paradigm, thus allowing for rich descriptions of the phenomenon.

Study Results: Connection to Research Literature and Addressing the Research Questions

This section will discuss the findings and how they address the research questions, while also tying the results to current research literature. First, I will discuss findings that addressed Research Question 1: *What does the lived experience of science teachers during the pandemic tell us about pedagogical judgment during the pandemic and pedagogical judgment in general?* This research question addresses four of the essential themes that emerged during my analysis of the data: (1) First Impressions of the Pandemic, (2) Confusion of the Pandemic, (3) A New Normal and (4) Technology as Aid and Hinderance.

First Impressions of the Pandemic

The six science teachers who participated in my research study all had strong first impressions of the COVID-19 pandemic as it related to their science teaching experience. The extreme first impressions, as described by the teacher participants', support the research literature, as teachers across the U.S. struggled with the new online teaching formats (Francom et al., 2021; Garcia & Weiss, 2020). The teacher participants shared that none of them had prepared for such an event and adjusting to such extreme changes overnight left them struggling to find ways to teach. In the first few days after

transitioning to online learning the teacher participants all voiced concerns about student attendance, student's access to lessons, and monitoring student's understanding. Sally described her first thoughts of the pandemic and preparedness succinctly:

> It started out very stressful and very crazy. In February there were rumors that COVID is going to make everyone shut down, but nobody knows for sure. Then we shut down on March 13th. We asked, "What does this mean? How are we gonna do this? Do the kids have internet at home?" It is all unknown, no plan whatsoever...The problem I had with it was, we didn't have any training on Zoom. Up to that point I logged into Zoom and was like, "Oh my gosh!"

Research literature supports these concerns, as they were salient across the U.S. (Francom et al., 2021; Reich et al., 2020).

The teacher participants' lived experience in the *First Impressions of the Pandemic* theme points to one of shock, questions, and unpreparedness for such an event as the pandemic. Their first impressions reveal a bit of fear, and the pedagogical actions of the teacher participants' show little movement during their first impressions of the pandemic. An extremely unprecedented event [COVID-19 pandemic] had halted the teachers' pedagogical judgment, if for just a moment.

Confusion of the Pandemic

All of the teacher participants in my study lamented the constant changing of lesson delivery (online synchronous or asynchronous, hybrid, and in-person socially distanced). Even taking attendance was complicated, as many school administrations had to develop new definitions for a student's "attendance" in class. Seth, Bella, Carol, and Sally all

voiced concern around students receiving the support they needed to succeed in an ever-changing educational environment.

In the research literature, many teachers focused on worksheets (Reich et al., 2020) review work (Francom et al., 2021) and educational videos (An et al., 2021) in an effort to quell some of the confusion of the tumultuous changes during the pandemic. Admittedly, the science teachers in my research study did utilize worksheets, review work and educational videos while teaching remotely during the COVID-19 pandemic. The teacher participants included in my research also strived to provide ambitious science teaching and equitable practices in innovative ways. Bella describes her use of fill-in worksheets while also trying to provide rigorous lessons remotely:

> When we were doing remote learning, it had to be stuff where they could either find the simple materials at home, if possible, or just had to be stuff that was done on the computer. We tried everything from Padlets[12], to Jamboards[13], to Flipgrids[14], where they could film their response. Lots of writing, lots, and lots of Google documents that they just filled-in or slide shows that they filled-in that way. We would build sentence stems and support videos that were linked along the way to make it as much ease of access for kiddos that were at home without support.

[12] A Padlet is a technology platform that facilitates communication. It can be used as an online noticeboard.

[13] A Jamboard is a digital whiteboard that allows for virtual collaboration on a common page.

[14] A Flipgrid is a video discussion platform.

This quote perfectly details the efforts the teacher participants made to calm the chaos of the pandemic through simple worksheets, while still providing equitable learning opportunities through sentence stems and support videos.

Bella used her pedagogical reasoning to continue to strive to provide equitable learning even though she was grappling with the confusion of the COVID-19 pandemic herself. Her tone in the above statement was one of shame, as though admitting to using fill-in worksheets was not a good teaching practice. The research literature also discusses worksheets, review work and educational videos as an unfavorable activity for learning during the pandemic. Though Bella mentions numerous times in her semi-structured interview that she and the students were "just surviving" the above excerpt shows that she was doing more than "just surviving." Bella had conflicting pedagogical responsibilities between providing equitable learning opportunities for students and the desire to maintain a work-life balance for her own mental health. She still found creative ways to reconcile the two pedagogical responsibilities and provide learning opportunities for all her students in equitable ways while balancing her work-life responsibilities.

The lived experience of the teacher participants' in the *Confusion of the Pandemic* theme reveal conflict in their pedagogical judgment. The teachers' were met with situations they had not experienced before, and this meant a reworking of their pedagogical actions to meet the new expectations. Their pedagogical judgment was being stretched and tested in finding ways to reconcile the unfavorable of worksheets and review work with the ideal of ambitious and equitable learning opportunities.

A New Normal

The essential theme of 'A New Normal' describes situations where teacher participants began adjusting to a different state of teaching and learning during the COVID-19 pandemic. This meant that the teacher participants were adapting to reduced student participation. In the research literature chronic absenteeism and reduced teacher/student communication (Francom et al., 2021; Reich et al., 2020) were often mentioned as key factors in providing quality science teaching during the COVID-19 pandemic. The teacher participants in my research study utilized their pedagogical judgment in creative ways to tackle these issues. Anna, Bella, and Ray spent extra hours developing a myriad of ways to connect with students socially and emotionally:

> I focused a lot more on getting the kids the social/emotional piece: "How are you today? Are you okay?" I always started my lesson with, "How is everybody doing?" Science is secondary. It was like, we are going through a tough time and I'm here for you. If I had any kids with an emotional issue that I needed to address, I would have kids work independently, and I would sit with them. Last year I had stuffed animals in my classroom for when kids were having a rough day I would just slide over the bin, and they would pick one.

Bella also had LEGOs for kids who needed something to manipulate with their hands, stamps and stickers as rewards and a calming notebook full of coloring pages and sudoku puzzles. Ray found ways to embed conversations about students' interests into lessons. Each day students would share one thing they were into. Students would share videos of them trying new skateboarding tricks or developing a video game. Anna dressed up a

skeleton each day that sat behind her during Zoom lessons, in an effort to make students laugh and desire to attend class to see how the skeleton was dressed each day.

Focusing on Social and Emotional Learning was a pedagogical action to hopefully increase student attendance and build communication between teachers and students during the pandemic. The pedagogical actions of the teacher participants helped them connect with students and engage students in learning. Adjusting to *A New Normal* meant connecting at a social-emotional level and taking extra time to check-in with students.

The lived experience of the teacher participants' during *A New Normal* reveals the flexibility in their pedagogical judgment. The pandemic stretched their pedagogy to rethink solutions. Movement towards the utopian ideal of ambitious and equitable science teaching required new ways to exercise their pedagogical judgment.

Technology as Aid and Hinderance

All six teacher participants shared that their school either already provided laptops and internet hot spots for each student prior to the pandemic or that their school developed methods to provide each student with a laptop and internet hot spot at the beginning of remote learning during the COVID-19 pandemic. There was quite a bit of confusion around providing laptops for unhoused students or students who moved frequently. Additionally, the internet hot spots were not immediately available at some schools in lower income areas. In the research literature access to technology, especially for vulnerable populations, also proved to be challenging (An et al., 2021; Francom et al., 2021; Reich et al, 2020).

Through self-taught methods each teacher participant in my study developed ways to increase accessibility for their students. All of the teacher participants held a strong

pedagogical responsibility to provide equitable learning opportunities for students. It was not surprising that they all spent extra hours, time, and effort to develop creative solutions for students to access science lessons and resources.

The teacher participants shared that technology implementation took significant amounts of planning hours. Bella, Sally, and Ray all spent numerous extra hours in the evenings, weekends and during school breaks teaching themselves how to use different technological resources in order to provide greater access to all of their students. Bella embedded links to numerous resources and text-to-speech features in all of her lesson slideshows. Sally taught herself how to record lessons and link them on a private website for her students to access at any time. Ray developed templates for online science lessons and taught his colleagues how to use the templates, in order to support his colleagues' use of online resources. Each teacher participants' pedagogical responsibility was to make learning science online not only accessible but available any time of the day, for any learning level, and to help their colleagues be successful with online implementation.

The most prominent feature of these teacher participants' pedagogical actions is the willingness and drive to use their own time outside of official work hours. Bella said she was spending approximately 20-25 hours a week outside of work hours developing lesson plans with text-to-speech features for her English Language Learners and numerous choices in lesson tasks to encourage choice and autonomy in the students learning. The large amounts of extra time these teacher participants spent teaching themselves how to use technology and provide quality online lessons speaks to their teaching pedagogy. Each teacher participant could have decided that a Zoom lesson and office hours, as required by most school administrations, was sufficient during such a chaotic time as the

pandemic. Yet each teacher participant decided that sufficient wasn't enough. Their students' equitable access to learning was important, and that meant extra hours, effort, and stress learning new technology and other resources.

The lived experience of the teacher participants' during the *Technology as Aid and Hinderance* theme show the teacher participants' absolute reliance on technology during the pandemic. Technology was so integral during the height of the pandemic that the teacher participants taught themselves how to use different technological resources, and spent extra hours embedding technological aids for students. The teacher participants' utilized their pedagogical judgment to move closer to an ideal educational situation.

Ambitious and Equitable Science Teaching

The findings from the final two essential themes: (5)Thoughts on Equity and (6) Facilitating Ambitious Science Teaching address the second research question:

Research Question: *How do science teachers navigate their pedagogical judgment in relation to ambitious and equitable teaching?*

Thoughts on Equity

The pedagogical responsibility towards equity was especially important to all the teacher participants during the height of the pandemic. During the semi-structured interview, the teacher participants mentioned equity as the first or second most important factor in their teaching pedagogy. Examples of how equity was operationalized through their pedagogical actions during the pandemic came out in numerous examples throughout the semi-structured interview. In the research literature three important features of equitable learning opportunities are: autonomy in learning, scientific discourse, and individual knowledge generation (Kolonich et al., 2018; Nasir & Vakil,

2017; Patterson, 2019). These features were exercised by the teacher participants in many ways, even when considering the uncertainty and ever-changing nature of teaching during the COVID-19 pandemic.

Autonomy is key in equitable science teaching and learning (Kolonich et al., 2018; Nasir & Vakil, 2017; Patterson, 2019). Anna did this through providing students with numerous choices in their learning:

> We also focused in the first stage of the pandemic on giving students choices. For example, in ecology you can read this article, watch this video or other stuff. It doesn't always lend itself to science, but I think being able to give kids choices when possible was definitely helpful in making me rethink things. So it wasn't all bad, it [the pandemic] has pushed us to be better.

When everything was uncertain during the pandemic, and many choices were being made for the students, Anna provided the students with some authority in their learning. A simple act of allowing students to make choices in the lesson could mean more engagement and greater success in learning.

Part of Ray's pedagogical responsibility meant he focused heavily on scientific discourse. The two school districts he taught in during the pandemic did not allow any kind of hands-on science. During remote teaching his administration was concerned about lack of supervision of students and during in-person teaching administration was concerned about socially distancing students to reduce COVID-19 transmission:

> Discussion was the best way to get folks involved and talk because if you give them time to just work on it, they could. We have the entirety of

> human knowledge right here, so leverage that in a way that you don't during an in-person class. We can talk things through with our peers and you can touch on all of this in an hour and a half, that is diverse and interesting.

During a strange time in education when almost all learning occurred via online methods, Ray chose to leverage the situation and encouraged students to discuss scientific topics with each other. His pedagogical action of focusing on scientific discourse allowed students to build relationships, learn how to share their opinions with evidence and discuss science concepts:

> So when I would ask a question or I had something up for discussion, people could unmute and talk, or they could write it down. So there was always an option whenever I asked for engagement or a question. I would say, there is a box on your screen with a question in it. I wanna hear about it and it is anonymous so don't worry about it. So I would pull up a response and be like, this is really good, this is a great point. Does the person who wrote this want to share, or can I?

Focusing on scientific discourse allows students the opportunity to be the authorities regarding science concepts. When students are the authorities in their learning, they take ownership of their learning (Nassir & Vakil, 2017). Ray's focus on this element of equity in learning provided students the opportunity to have a voice, when often, online learning can be a passive endeavor. His pedagogical reasoning to lean into scientific discourse — when hands-on inquiry was not a possibility — provides insight into his knowledge of science education. A scientifically literate student needs more than hands-on activities

(Singer et al., 2016). Students need meaningful ways to participate (Windschitl et al., 2020).

Providing students with the opportunity to be the knowledge generator and authority related to their learning is an important element of equitable learning (Nasir & Vakil, 2017). Bella developed a remote lesson about light and how it moves through objects. Students were required to develop their own experiment to test light movement, then write a scientific paragraph using correct terminology to describe their findings and support their reasoning for how they designed their experiment. Anna asked her students to develop an experiment around mutualistic relationships of animals and Seth had students explore the redshift during the Big Bang. In each of these lessons, the students were the knowledge generators, and the teachers were facilitators enacting their pedagogical responsibility. When the students had the opportunity to be the knowledge generator, they were the authority in their own learning, thus allowing for all students to be successful learners (Kolonich et al., 2018).

The tremendous changes and turmoil of the COVID-19 pandemic provided ample opportunity for the teachers in my study to showcase their innovative nature. Each teacher participant was doing more than just thinking about *how* to embed equitable practices into remote, hybrid and socially distanced learning, they used their pedagogical reasoning to take action on the *how*. Equity in learning meant the teachers spent extra hours to learn how to use new technology resources, how to conduct scientific discourse safely in an online space, and how to integrate autonomy into lessons that were increasingly being dictated by administrators. The pedagogical responsibility to navigate

equity when it is easier to ignore, given the extreme conditions of the pandemic, point to science teachers who have integrity.

The lived experience of the teacher participants' in the *Thoughts on Equity* theme reveals the resiliency of the teachers' pedagogy. When the state of education had completely changed, the teacher participants' equity ideals did not. Equitable learning opportunities for students was a core pedagogical responsibility for all the teacher participants and this was consistently evident in their pedagogical actions.

The Facilitation of Ambitious Science Teaching

The pursuit of ambitious science teaching during the pandemic continued for all of the teacher participants. Just as in the research literature, students should be the knowledge generators (Kazempour & Amirshokoohi, 2014; Lesseig et al., 2016). Anna explained how she provided opportunities for the students to be experts:

> My AP students have done questions like "what happens to duckweed when sunscreen is added to water?" So they grow duckweed in the lab, and they add different amounts of sunscreen because they say, "we're going swimming with sunscreen." Then we go through the whole scientific process, and we analyze some past papers, looking for what makes good research and what doesn't. Then they end up writing their own paper. I think this is my answer to "Let's not have students just pretend to do science. Let's actually have students do science."

The opportunity for students to build data driven explanations based on their own research and findings, provides opportunity for rich scientific learning where the student

has taken ownership of their learning (McLaughlin & McFadden, 2014; Singer et al., 2016).

The ability of the science teacher to assume the role of facilitator and encourage kids to be the knowledge generators is challenging. Pedagogically, a teacher must value the students' development of knowledge and understand that knowledge is gained through ownership of the learning (Kazempour & Amirshokoohi, 2014; Lesseig et al., 2016). Though it may be challenging to step-back and allow the students the space to navigate the learning under their own terms, it yields a greater learning experience. All six teacher participants found ways to navigate the role of facilitator during the pandemic. Whether through providing the students with the opportunity to be the knowledge generators (Anna and Seth), modifying scientific inquiry (Bella, Carol, and Sally), or engaging the students in scientific discourse (Ray), ambitious science teaching through facilitation occurred. The pedagogical judgment exercised by each teacher participant in assuming the role of facilitator, provides strong evidence that each teacher participant values the student's development of knowledge, even when the learning environment is not optimal.

During the semi-structured interviews, I found that some of the teacher participants used the term *hands-on science* when specifically asked to describe scientific inquiry in the classroom. The research literature also expressed this finding (Lederman et al., 2014; Kazempour & Amirshokoohi, 2014; Lotter et al., 2018), where some science teachers were conflating scientific inquiry with hands-on science. My purpose in collecting multiple types of data from the teacher participants; semi-structured interviews, a Qualtrics survey and lesson plans, allowed me to analyze the data to determine *how* the teacher participants were thinking about science teaching. While hands-on science did

occur, I was able to discern that scientific inquiry also took place. This meant teachers were embedding elements of the scientific method in lessons and students were the drivers of the scientific questioning.

In the Qualtrics survey, each teacher participant provided examples of facilitating scientific inquiry in determining how to teach specific science concepts (Appendix H). Additionally, the provided lesson plans (Appendix F) showcase opportunities for scientific inquiry. The multiple points of evidence — interviews, Qualtrics survey and lesson plans — show that scientific inquiry was occurring. The teacher participants were thinking about scientific inquiry (lesson plans), facilitating lesson plans (semi-structured interview responses), and valued scientific inquiry (Qualtrics survey) as a method of teaching, and learning science. The pedagogical responsibility the teacher participants held to facilitate scientific inquiry was evident throughout all the data.

In the research literature, communities of practice are a major factor that encourages teachers to facilitate scientific inquiry (Lederman et al., 2014; Singer et al., 2016; Stroupe et al., 2021). Bella, Ray, Sally, and Seth were involved in a community of practice. It is through the community of practice that the teacher participants found support and worked with colleagues to develop new and innovative ways of doing scientific inquiry. During the pandemic there was minimal evidence of the teacher participants collaborating with their communities of practice. But the four teacher participants mentioned their communities of practice as salient in their decision making around lesson development prior to the pandemic. Interestingly, the research literature does list confidence in implementation of scientific inquiry and a gradual change in pedagogical content knowledge as results of participating in communities of practice (Lederman et al., 2014;

Singer et al., 2016; Stroupe et al., 2021). Based on the research literature, I infer that the teacher participants drew upon their previous experiences in their communities of practice to find innovative ways to implement scientific inquiry during the pandemic.

A study of math teachers striving for ambitious and equitable teaching during the pandemic, details that many developed their own instructional videos for students (Horn & Schneeberger McGugan, 2020). The purpose of the videos was to teach a specific math concept but hopefully to also build some connection with the students during a time when connections were minimal, yet sorely needed. Carol, Sally, and Seth also developed instructional science videos in an effort to connect with their students. The pedagogical action of connecting with students — while also teaching via video — points to equitable science teaching. The teacher participants looked for avenues to connect with their students in a new way while providing rigorous science instruction.

Through exploring the pedagogical judgment, the teacher participants exercised in relation to ambitious science teaching, considering scientific inquiry specifically, it is clear that each made tough choices to continue facilitating ambitious science teaching during the pandemic. The pre-pandemic communities of practice provided a background of knowledge around scientific inquiry. The scientific inquiry background knowledge provided a backdrop in the teacher's pedagogical knowledge in which to begin thinking of innovative ways to facilitate inquiry during a chaotic time. Even though some teacher participants verbally conflated hands-on science with scientific inquiry, it was clear, given the evidence, that scientific inquiry occurred in all the teacher participants' classrooms. Additionally, the teacher participants employed other elements important in ambitious science teaching, including individual knowledge generation and building

meaningful connections with students. The pedagogical actions of the teacher participants during the COVID-19 pandemic paid-off, rigorous ambitious science teaching occurred, even with all the uncertain and chaotic circumstances surrounding the pandemic.

The lived experience of the teacher participants in *The Facilitation of Ambitious Teaching Methods* theme reveals the importance of science inquiry and other ambitious tenets to the teacher participants' pedagogy. Not being able to conduct hands-on experiments at home or even socially distanced at school, meant the teacher participants needed to use their pedagogical judgment to move towards a more desirable educational situation. The educational situations the teacher participants facilitated was innovative and still rigorous.

Assumptions and Bias

A practice commonly used in hermeneutic phenomenology is to journal any preconceived ideas or bias around the participants' experiences (Billups, 2021; Peoples, 2020). I journaled my preconceived ideas immediately after each semi-structured interview and prior to beginning data analysis. The purpose in journaling any preconceived ideas or bias was to make my assumptions explicit, as the researcher. Then after analyzing all of the data, I circled back to the journal entries while considering the information gained from analyzing the data to arrive at a new understanding of the participants' lived experience. This practice, called the hermeneutic circle, provides an avenue for the researcher to view the phenomenon more holistically from the participant's eyes.

One of my most salient assumptions prior to beginning this research was that the teacher participants would have found it too challenging to facilitate an equitable

classroom environment while focusing on ambitious science teaching during the height of the COVID-19 pandemic. Thus I predicted that the teacher participants I would interview would rely heavily upon review work, worksheets, and simple computer simulations, as found in the research literature (Francom et al., 2021; Reich et al., 2020). After each semi-structured interview I journaled my first thoughts of the teacher participant's lived experience. This journaling exercise using the hermeneutic circle (Peoples, 2021) was beneficial in examining my initial thoughts and impressions of a teacher's experience. The journals I wrote after four of the open-ended interviews describe my absolute wonderment of the teacher participant's lived experience and their resilience in facilitating ambitious science and equitable teaching during the pandemic. Below are excerpts from my journal entries that took place immediately after the semi-structured interview:

Journal Excerpt After Ray's Interview

He was incredibly passionate about teaching, loves teaching and all of his examples of how he taught were high quality, scientifically sound in practice, rigorous and just plain fun.

Journal Excerpt After Bella's Interview

Truly one of the teachers who "got it" when it came to rigorous, equitable, inquiry-based teaching…. The lesson plans she provided me are stellar, with scaffolding and differentiation, engaging, interactive, and allowances for equity (text-to-talk features in all her lessons).

After analyzing the data, I found that all of the teacher participants were extremely resilient and consistently strived to facilitate lessons that focused on aspects of ambitious

science teaching and equity during the tumultuous circumstances surrounding the COVID-19 pandemic. I was shocked and impressed with the teacher participants' pedagogical responsibility to ambitious science teaching and equity even during virtual learning, low student involvement and attendance, and strict administrative rules around science labs and hands-on science.

Summary

The six essential themes I uncovered during analysis of the data point to a lived experience of the teacher participants' that was complex and flexible. The pedagogical judgment the teacher participants' exercised was constantly being stretched in new ways due to the constant influx of unfavorable circumstances around the pandemic. The research literature and my research findings provide evidence of the essential themes, specifically around equitable learning environments, facilitating ambitious science teaching, and the hardships of teaching science during the pandemic. At the same time, the research literature and my research findings differed in several areas. Unlike studies in other settings (An et al., 2021; Francom et al., 2021; Reich et al., 2020), the access to technology was not as much of a hardship for teachers and students in my research findings as presented in the research literature. This difference in access to technology might be due to the school districts the teacher participants' worked in. Four teacher participants worked in middle-upper income serving school districts and one teacher participant taught at a tuition-based private school, where parents with more disposable income could afford to enroll their child. Overall, the six essential themes bring together a lived experience of science teachers that aligns with the current research literature and

points to a stressful time in education where the teacher participants stretched their pedagogical judgment.

One of the most poignant features I noted during my semi-structured interviews with the teacher participants was the resiliency of the participants and the constant striving to provide equitable and ambitious science learning opportunities for their students, even in light of the personal sacrifices the teacher participants made for their students. My theoretical framework centering on hermeneutic phenomenology, pedagogical judgment, and ideal/non-ideal theories allowed me the opportunity to delve into the lived experience of the teacher participants, to *see* what they lived during the pandemic. While the research literature provided data, I was allowed the opportunity to find out the *why* of the data. The teacher participants were more than happy to share their thought processes and decisions related to science teaching while navigating the extremely chaotic situations presented during the pandemic. Their stories of hardships and triumphs were enlightening, and their stories shed light on the overall phenomenon of teaching science during the COVID-19 pandemic.

Implications, Future Research and Limitations

This section highlights the implications, future research recommendations and limitations of my study. The implications I uncovered while collecting and analyzing data has highlighted some actions and changes needed in education as a result of my findings. Additionally, I will explain how my research provided much needed insight into the experiences of science teachers during the COVID-19 pandemic. The lived experiences and essential themes I interpreted in this study have implications for future research and practice. I will explain and expand on the future directions I would like to research based

on my current findings. Finally, I discuss the limitations of this research study and how it affected the results of my study.

Implications

The foremost reason for conducting this research was to give voice to science educators and their lived experience during the COVID-19 pandemic. I was unable to find any research literature that focused on the science teacher and their experience teaching during the pandemic. It is through my research that I have shed light on the myriad of dilemmas and choices teachers experience daily in facilitating ambitious and equitable methods in the classroom. The COVID-19 pandemic provided an extreme situation in which all of the pedagogical judgment the teachers exercised was intensified due to the tumultuous nature of the event. Through sharing the teachers' lived experiences, I hope other teachers may find comfort and support in their stories.

This dissertation study may inform curriculum writers, of how to prepare lessons that are flexible in implementation yet are still rigorous in their facilitation of ambitious and equitable teaching. Administrators may use this research to inform them *how* to support their teachers, especially during extremely disruptive events. Teacher education programs at colleges and universities could use these lived experiences as examples of how to prepare future educators for disruptive events. The excerpts and stories behind the teachers' experiences provide ample ground for future learning in response to disruptive events. My hope is that educators read these stories and learn from them.

Preparation for Future Disruptive Events

This phenomenon of teaching science during the COVID-19 pandemic illustrated several problems that educators face related to preparation for extremely disruptive

events in education and support from colleagues and administration. All six teacher participants stated they were not prepared for such an extreme upheaval to every facet of their teaching. I recommend that schools, teaching departments, and districts place priority on planning for future such events. Sally and Seth shared that their school district provided lessons for implementation during the pandemic. According to both of these teacher participants the lessons were very vague, did not align with the current science concepts they were covering, and didn't account for the teachers' relationships with the students. In short, teacher participants were stifled in their pedagogical judgment when modifying the provided lessons, even though the teachers had been with the students for almost the entire school year and were well aware of the needs of their students.

Though this study focused on an extremely chaotic event, the COVID-19 pandemic, there are wider implications related to a teacher's pedagogical judgment and other issues that require a teacher to negotiate their educational priorities and actions. For instance, a school district might implement a new policy that requires a teacher to rethink their pedagogical responsibilities around lesson format or delivery. A new science curriculum or initiative to integrate social-emotional learning into classroom facilitation would mean a teacher would need to exercise their pedagogical judgment in new ways. These above instances are not as extreme as a pandemic, but do present scenarios in which teachers will be utilizing their pedagogical judgment to negotiate the changes.

Technology Training

These past three years have shown educators that anything can and will happen, including the entire world shutting down due to a virus. We need to take the time to prepare for future events that disrupt education. This means more than just making sure

all the students have laptops and an internet connection. Teachers need to be sufficiently — more than one hour — trained in the technological platforms they are required to use. Teachers should also be allowed pedagogical judgment when planning for such unexpected events. They know the needs of their students and are professionally trained. This might look like a week or two-week break from teaching and student learning in the event of an extremely disruptive occurrence. With a break, teachers and administration can begin planning according to the needs of students based on the severity of the disruptive event. It is impossible to prepare for the unknown, but educators can prepare in-light of our history. Our knowledge of the experiences of the past three years have shown us that educators are capable of preparing for rigorous learning despite the pandemic and quality learning occurred despite all the disruption.

Supporting Teachers

Unfortunately, three of the teacher participants left the teaching profession as a result of their experiences during the COVID-19 pandemic. Each of them cited unsustainability and a lack of support as reasons for leaving. This sad fact brings me to my final suggestion for change within education. As an educational community we need to support our teachers. Bella stated she experienced suicidal ideation at one point during the COVID-19 pandemic because she was working so many hours and trying so hard to provide everything for everyone. She even reached out to her administration asking for help, when she was told, she was "a new teacher and the stuff [she] was experiencing is typical new teacher stuff." Ray said he was in a very dark place at the start of the pandemic and was making a "last ditch" effort to develop an amazing science unit for his

students, when the COVID-19 pandemic essentially shut everything down. He said he felt as though everything he had been working on was a waste of time:

> Right before the pandemic hit, I was working on a project based on light with all these gigantic toolboxes of things. And it was all about just discovering experimentation and finding things out on your own and doing group work. Then the pandemic hit right in the middle of it. It was difficult because I was in a very difficult school, brutal environment. And this was kind of me trying to pull myself out of it, trying something new and doing something big and experiment based.

Sally was incredibly discouraged with how she was treated at her school during the pandemic, even after she had been teaching there for seven years. Sally had received ADA accommodations to remain home and teach virtually the entire 2020-2021 school year because her husband had some health concerns. When she asked to attend graduation in June to support her students graduating, she was told she could not attend. This situation was the final factor that led her to resignation. These teachers were literally risking their wellbeing and the wellbeing of their loved ones to provide quality science instruction and support for their students, when they themselves were not receiving the support they needed to continue teaching.

Science teachers need a network of support, to rely on and glean wisdom from during challenging times. The network should consist of colleagues and administrators in their school and colleagues outside their school, possibly within the same school district. The network's purpose is to check-in regularly with the members and provide unbiased support when needed. This might look like focusing on social and emotional learning for

teachers, or a day off for the teachers to focus on their mental health. Four of the teacher participants interviewed stated that simply talking about their experiences teaching during the pandemic was incredibly therapeutic. A network might function as a space for teachers to debrief stressful events. As educators, we need to remember that teachers are human, too, and need avenues to express their feelings, receive support and take a day off when needed. If the education sector continues operating in the same manner we have been for the past five years, then we will continue to lose quality teachers. If we continue to lose quality teachers, then our students will suffer the most as a result.

The science teachers in my study recognized the need to integrate social-emotional learning into lessons and interactions with their students. Yet, I am unaware of any social-emotional learning or support provided for the teachers during the pandemic. The entire educational system in the U.S. needs to look at social-emotional learning for both educators and students. After the chaotic and traumatizing events surrounding the pandemic, we need to focus on the social-emotional health and supporting those most deeply affected.

Looking back at the last several years of teaching during the pandemic, it is vital that we give voice to those 'on the front lines' of teaching. I hope my dissertation research serves as a starting point for highlighting the lived experiences of teachers during stressful events. We need to honor and respect the teacher's experiences and knowledge concerning teaching and their students. We also need to provide opportunities for teachers to decompress and find support during highly tumultuous events. My research has reminded me that teachers care deeply about their profession and their students, to the point that they will risk their health and wellbeing.

Future Research

The lived experiences and essential themes interpreted during my research have revealed an abundance of information around science teachers' experiences during the COVID-19 pandemic. Given the data I collected, there is still more information to be uncovered related to teachers' experiences teaching during a highly stressful and unpredictable event. Below, I recommend two areas for future research.

Longitudinal Study of Teacher Participants

A longitudinal study around the long-term effects of the COVID-19 pandemic would be a beneficial research study. During the semi-structured interviews with teacher participants, I made sure to ask each participant if they believe there were any benefits to teaching during the COVID-19 pandemic. Despite all the extreme changes in school protocols, lack of technology training and lack of administrative support, all of the teacher participants stated that the increased use of technological resources in the classroom benefited the teachers and students. A valuable next step in this research would be to interview the same teacher participants still in the field, in two years to determine how increased technological resources have been employed and have changed the teachers and students.

Social and Emotional Learning

Half of the teacher participants in my study mentioned a focus on social and emotional learning as a benefit during the pandemic. Anna, Bella, and Ray all mentioned purposefully integrating social and emotional learning concepts into their lessons during the pandemic. It would be worthwhile to research how social and emotional learning has

been facilitated in classrooms since the pandemic and how it has affected teachers and students.

Limitations

While the results of this study offer descriptive insight into the lived experiences of science teachers during the COVID-19 pandemic, this study has limitations particularly with generalizability of the findings. The phenomenological methodology and small sample size preclude conclusions about science teachers experiences during the COVID-19 pandemic beyond the sample. Although steps were taken to increase the validity of the findings, there are several limitations to this study as a result of my methodological decisions.

Number and Ethnicity of Participants

Although a sufficient number of participants were enrolled in this study given the qualitative design method chosen (Creswell & Poth, 2018), a larger pool of participants may reveal additional insights and experiences. In addition, all of the six participants were white; thus the findings from this study may not be transferrable to teachers of other ethnicities.

Geographic Location of Participants

The six participants included in this study resided in the Mountain West, Midwest, Northeast, and New England states. Although I concentrated efforts in distributing my study flier to the West Coast and Southeast, I was unsuccessful in recruiting participants from those two geographic areas. A teacher participant from the West Coast and Southeast would add to a more robust study encompassing all the geographic areas in the United States. Because of the variation in state and local governments' responses to the

pandemic, representation across geographic areas would make the study more generalizable to science teachers' experiences teaching during the COVID-19 pandemic in the United States.

In-Field Observations

The chosen forms of data collection were limited to Qualtrics surveys, semi-structured interviews, artifact collection and researcher journaling. Another common form of data collection commonly used in phenomenological studies is observation (Creswell & Poth, 2018). Due to the risk of virus transmission and regulations set-forth by school districts and my institution's IRB, in-class observations were not a possibility. Additionally, many teachers and students were still partially conducting class virtually outside the classroom walls. This form of data collection would have contributed to first-hand evidence of teachers facilitating equity and ambitious science methods.

Chapter 5 Summary

The phenomenon of teaching science during the COVID-19 pandemic is one of strong and lasting experiences that have carried over into the teacher participant's lives post-pandemic. All six participants commented that they were 'just surviving' and 'doing the best they could.' Through my data collection and analysis, I have found that the teacher participant's 'just surviving' and 'doing the best they could' was phenomenal and these six participants are incredibly resilient. The teacher participants took the extremely unfavorable circumstances handed to them during the height of the pandemic and reworked their pedagogical judgment to meet the new circumstances with innovation. Ambitious science teaching occurred in many different ways, through modified scientific inquiry, rethinking implementation of data-based discussions, and opportunities for

students to make choices about their learning. Equity was so salient in the teacher participants' pedagogical judgment that it was continually being discussed, rethought, reworked, and integrated into every aspect of their daily interactions with students. The lived experience of the teacher participants throughout the six essential themes show their desire to move towards more ideal educational opportunities in both ambitious and equitable science teaching.

Looking at the participants' experience through the researchers lens according to hermeneutic phenomenology has revealed some new understandings within my context as researcher. The center of the experience (Heidegger, 1971), for me, was the teacher participants' absolute resiliency in spite of all the hardships. Throughout the interviews with the teacher participants, and my journaling using the hermeneutic circle, I realized I could not give-up on them. Their stories needed to be told and it was my role as researcher to highlight their lived experience.

I hope that my descriptions of their lived experiences bring new insights into the world of science teaching and encourages further research in this area. Though many of the issues described by the participants aligned with the research literature, there were also new findings. Additionally, the hermeneutic phenomenology methodology brought to light a new perspective of what it was like teaching during the pandemic and added nuanced details into teachers' pedagogical judgment regarding their decisions and teacher moves. I admire the six teacher participants who generously gave of their time to share with me their tumultuous experience teaching during an extremely stressful time in education.

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Appendix A

Qualtrics Survey

Think about your own teaching pedagogy in reference to the questions below. It is not necessary to have taught the subject matter or grade. Given the possible responses how would you teach the lesson. Please provide a rationale for your choice.

1. Frog dissection 1

Mr. Goodchild is doing a frog dissection with his 10th graders to help teach them about anatomy. Thinking about how you would teach a lesson, of the following, which is most similar to what you believe is the best way to incorporate a dissection into a lesson?

a. It should be used as a stand-alone step-by-step activity for students to explore the frog's anatomy and raise discussion questions on their own.
b. It should be used as a follow-up step-by-step student activity after Mr. Goodchild explains exactly what students will need to notice about the frog anatomy.
c. It should be used as a step-by-step student activity while answering probing questions, followed up by teacher-led discussion and clarifications.
d. It should be used as a step-by-step demonstration by Mr. Goodchild while he explicitly points out what students need to know about frog anatomy.

Rationale for choice:

2. Soil porosity

Ms. Cubbage's 7^{th} grade science class has been learning about soil types by observing soil color and texture (particle size). While making observations of soil samples, the students notice that some soil types seem more "fluffy" than others. Ms. Cubbage realizes that her students are referring to *porosity* (how densely the materials are packed together, ability to allow water to move through) which is one of the key concepts later in her unit.

Thinking about how you would teach this lesson, of the following, which is most similar to how you would respond to the students' observation?

a. I would congratulate the students on such a good observation, then explain to them *porosity* is a description of how densely packed soils are. I would then tell students how to test soils for it and follow up by doing tests on our soil samples for porosity.

b. I would congratulate the students on such a good observation and ask them what they thought they were looking at. Through discussion I would try to get them to think about packing and how one might test for packing. We would do tests and based on their findings; I would introduce the concept of *porosity*.

c. I would recognize that what is most important here is that the students were being independent investigators, not necessarily that they were stumbling upon the idea of *porosity*. I would simply encourage their scientific attitudes and have them continue their investigations.

d. I would congratulate the students on such a good observation, then explain to them that what they observed was called *porosity*. Using a demonstration, I would show the students that more porous soils are less packed, and that water moves more easily through porous soils.

Rationale for choice:

3. Ms. Baker is teaching her 8^{th} grade students the law of reflection: when a ray of light strikes a mirrored surface, it leaves at the same angle as when it arrived. Ms. Baker has to decide how she will teach the lesson. Thinking about your own teaching, of the following, which is most similar to how you would teach the lesson?

a. I would write the law of reflection on the board and illustrate with a diagram. Next, I'd show them a real example, using a light ray source, mirror, and protractor. Then we would discuss any questions the students might have.

b. I would ask students to find out what they can about light behavior around mirrors by exploring on their own with an assortment of available items, including light ray sources, mirrors, and protractors. Then the students would report back on what they did and what they found out.

c. I would first pose a question about reflection for the students to explore. The students could investigate using light ray sources, mirrors, and protractors, and then discuss their findings. I would close the lesson by giving them a summary of the law of reflection.

d. I would write the law of reflection on the board and illustrate with a diagram. Then I'd have the students verify the law using light ray sources, mirrors, and protractors. We would then discuss their findings.

Rationale for choice:

For the below questions consider your teaching and classroom prior to the COVID-19 pandemic.

4. In your own classroom, when students don't learn as expected, what do you find are the reasons?

5. What are some of the major challenges of teaching science in this school?

6. With a diverse mix of student's knowledge and abilities in the classroom, what are some of the strategies you use to address that?

Thank you for taking the time to fill-out this questionnaire. I will contact you within the next 48 hours to schedule a brief interview.

Questions 1-3 adapted from *Pedagogy of Science Teaching Test (POSTT)* by Schuster, et al.
Questions 4-6 adapted from *Views of Students Mathematical Capabilities (VSMC)* by Jackson, et al.

Appendix B

Semi-Structured Interview Protocol

Lived Experience of Science Teachers During the Pandemic

Date: Time & Place:

Interviewer: Interviewee:

Opening the Interview Session

Introduce the topic and establish rapport with the participant.

Script

The purpose of this interview is to hear about your experience with teaching science during the COVID-19 pandemic and how you describe that experience by sharing your personal stories, insights, reactions to, and interpretations of those experiences.

Introductory Questions

How long have you been teaching?

What sciences are you currently teaching?

What is one aspect of teaching that you enjoy?

Key Interview Questions

1. Tell me about your overall experience teaching during the pandemic.
   a. What were the challenges?
   b. What were some successes experienced?

2. How would you describe a typical day teaching during the pandemic? Provide examples during **remote** teaching **and** during the initial **return** to in-person teaching.
   a. How is this different than a typical day teaching pre-pandemic?

3. What did lesson planning look like pre-pandemic and during the above two situations? (**Remote** and initial **return** to in-person)

a. What new considerations needed to occur when developing lessons during the pandemic?

4. Tell me about your teaching pedagogy.

a. What is important to consider when teaching?
b. Were there any elements of your teaching pedagogy that may be more or less important during the pandemic?

5. When State, District, School regulations changed according to the increase/decrease of COVID-19 cases, how did this affect the choices made for class instruction? Describe an example:

6. In order of importance (rank the features) what feature/elements were most important for classroom instruction during the pandemic? (Examples: hands-on science, scientific inquiry, evidence-based discussions, review, scientific writing, equitable access to resources or other elements). *Provide an example of each.

a.
b.
c.

7. Discuss any dilemmas in choice or implementation of above features/elements. Example: Providing opportunities for scientific inquiry was important but hard to implement due to asynchronous teaching or lack of student's resources at home).

8. How did you address student's diverse abilities and needs in the classroom during the pandemic?

a. Was this operationalized differently pre-pandemic?

9. When students did not learn as expected during the pandemic, what did you find were the reasons?

a. What did you do in response to the above question, to help students learn?

10. Looking back at the previous two years of teaching during the pandemic is there anything you would have done differently?

a. Are there any aspects/elements of teaching you began implementing during the pandemic that you will continue to use in the future?

Concluding the Interview

11. Is there anything else you would like to share pertaining to your teaching experience during the pandemic that was not captured in the questions above?

Thank you and Follow-up Reminder

Script

Thank you for your time and your insights on teaching science during the COVID-19 pandemic. I will follow-up with you in the next week to complete a member-checking exercise to verify my notes of our session and/or to ask you a few questions for clarification.

Adapted from Phenomenological Lived Experience Interview Protocol in *Qualitative Data Collection Tools: Design, Development, and Applications* by Felice D. Billups

Appendix C
Recruitment Email

Dear { }

My name is Amy Vo, and I am a PhD student from The Teaching and Learning Sciences at the University of Denver. I am writing to invite you to participate in my research study about science teachers' experiences and pedagogical choices during the COVID-19 pandemic. You're eligible to be in this study because you are a secondary science teacher. I obtained your contact information from{ }.

If you decide to participate in this study, you will answer a series of open-ended interview questions pertaining to your classroom experiences during the COVID-19 pandemic.

Remember, this is completely voluntary. You can choose to be in the study or not. If you'd like to participate or have any questions about the study, please email or contact me at amy.vo@du.edu or ph: 207-400-7451.

Thank you very much,

Amy

Appendix D

Study Flyer

Participants needed for a study examining the experiences of Secondary Science Teachers during the COVID-19 Pandemic.

The University of Denver's Department of Education is conducting a research study on: Secondary Science Teacher's Pedagogical Judgment During the COVID-19 Pandemic. If you taught science in grades 7-12 at a U.S. school during the COVID-19 pandemic, you may qualify for a research study examining the pedagogical judgment teachers exercised related to ambitious and equitable science teaching. Participants will complete a brief survey and interview related to their experiences teaching during the COVID-19 pandemic. A lesson plan used during the COVID-19 pandemic may also be requested.

For more information, please email Amy Vo at amy.vo@du.edu or call 207-400-7451.
Principal Investigator: Amy Vo, PhD Candidate, University of Denver, College of Education
Faculty Sponsor: Dr. Brette Garner, Assistant Professor, University of Denver, College of Education
This study has been approved by the University of Denver Institutional Review Board
https://img.freepik.com/free-vector/flat-design-biotechnology-concept-illustrated_23-2148893543.jpg?size=338&ext=jpg&ga=GA1.2.1294828568.1655237587

Appendix E

Coding and Scheme for Qualtrics Survey

POSTT[15]
Description of Science Instruction

Epistemic Mode	Variant (Direct or Inquiry)	Description of Action
Science presented as facts to remember…	1-Didactic Direct	Teacher presents and explains science content…illustrates with example or demo. No student activities.
	2-Active Direct	Teacher presents and explains science content….students engage in verification or confirmation.
Science as developed by process of inquiry…	3- Guided Inquiry	Students actively explore phenomenon in question with teacher guidance.
	4- Open Inquiry	Students actively explore phenomenon as they choose, and teacher facilitates but does not prescribe.

Example Key for Items

1- Frog Dissection
A- 4 Open Inquiry
B- 2 Active Direct
C- 3 Guided Inquiry
D- 1 Didactic Direct

2- Soil Porosity
A- 2 Active Direct
B- 3 Guided Inquiry
C- 4 Open Inquiry
D- 1 Didactic Direct

3- Reflection
A- 1 Didactic Direct
B- 4 Open Inquiry
C- 3 Guided Inquiry
D- 2 Active Direct

[15] Adapted from: Cobern, William W. et al. (2014). Pedagogy of Science Teaching Tests: Formative assessments of science teaching orientations. *International journal of science education* 36.13 2265–2288. https://doi-org.du.idm.oclc.org/10.1080/09500693.2014.918672

VSMC[16]

Example dialogue and scheme for coding VSMC responses

Coding Scheme to Assess the Nature of Teachers' Explanations Around Students' Difficulties in Science

Code and Definition	Example of Coded Transcript
Productive Student performance is explained as a relationship between the student and instructional opportunities.	**When students don't learn as expected, what do you find are the reasons?** Usually, the reason students didn't learn well has to do with how I ordered the lesson, explained a concept, or had them try to demonstrate it. **With a diverse mix of students' knowledge and abilities in the classroom, what are some strategies you use to address that?** Providing experiences in the classroom through exploration of phenomena allows students to have a shared point to build knowledge. Skills can then be scaffolded to support analysis, discussion, and sharing of evidence in constructing ideas and concepts in science.
Mixed Student performance is explained as a relationship to: 1. the student and instructional opportunities And 2. is due to the properties of the student or something other than instructional opportunities.	**When students don't learn as expected, what do you find are the reasons?** Sometimes students don't have a good foundation because they never cared about science the way it was taught in the past… I also had students with a variety of learning needs, …once I learned how they thought about things, I could adapt my teaching style to meet their needs.
Unproductive Student performance is explained as a property of the student (e.g., lazy, uninterested) and/or is due to the relationship with something other than instructional opportunities (e.g., family doesn't care about education).	**What are some of the major challenges of teaching science in your school?** Highly variable ELL levels and bilingual education was the biggest challenge, as well as low attendance rates for many students, and extremely different comfort levels with concepts coming into the science class.

[16] Adapted from: Jackson, K., Gibbons, L., & Sharpe, C. J. (2017). Teachers' views of students' mathematical capabilities: Challenges and possibilities for ambitious reform. *Teachers college record*, *119*(7), 1-43. https://doi-org.du.idm.oclc.org/10.1177/016146811711900708

Appendix F

Lesson Plan & Artifact Collection Rubric

Document/Artifact	Source of artifact	Ambitious practices consistent with findings (Scientific Inquiry)	Equitable practices consistent with findings	Divergence from findings
Lesson plan 1 -Interactions between populations (Biology lesson) Delivery -Fully virtual	Anna	Provided choices for the students in the lesson.	Pandemic lesson plan that emphasizes numerous times the desire to "see" the students virtually. Wanting to connect with the students. Provides Google Meet for students to check-in if desired.	Did not see evidence of accommodations for diverse learning needs.
Lesson plan 2 -POGIL (Process Oriented Guided Inquiry Learning) Cellular Respiration Delivery -Fully virtual	Anna	Rigorous inquiry that can be completed virtually		
Lesson Plan 3 -Virtual onion root lab -HHMI (Howard Hughes Medical Institute) Cell Cycle Interactive Delivery	Anna	Virtual lab allows the student to be the driver of the inquiry (mitosis onion root tip lab). Cell Cycle allows student	Presents concepts in multiple modes for diverse learning needs. Provides accompanying worksheet in Spanish	

-Fully virtual		to be driver of exploration.		
Lesson plan 4 -Function of organelles in a cell -Surface area to volume ratio lab -Organelle speed dating activity Delivery -Hybrid	Anna	Alternative forms of assessment besides a test to accommodate the virtual environment. Provided virtual lab options for absent students. Lesson was connected to student's interest (speed dating) so real-life/fun.	Speed Dating Activity-allows students to be leaders. Alternative forms of assessment.	
Lesson plan- -Measuring & Expressing Enthalpy Changes Delivery -Hybrid	Carol	Webcam for remote students to follow along and interact with in-person lab partners. All files are accessible on classes Microsoft Teams page.		Did not see evidence of accommodations for diverse learning needs.
Lesson Plan -Lenses and Color Delivery -Hybrid	Ray	Provides different modalities in lesson. Lab encourages individual exploration. Provided enrichment activities for further exploration.	Provided enrichment activity - students needed to engage in scientific discussion with peers.	Did not see evidence of accommodations for diverse learning needs.
Lesson Plan 1 -Waves	Bella	Provides Interactive Reader Different	Emphasis on relationship building with students and	

Delivery -Fully virtual		modalities (reading, video, listen to slides read, interactive slides, simulation of waves, lots of images for help with vocabulary)	checking-in on student's well-being. Opportunity for students to connect learning to current life situations.	
Lesson Plan 2 -Extensions of Lessons and Calm Room Delivery -Fully virtual	Bella	Extensions: provides further exploration websites pertaining to current concepts being covered in class.	Calm Room: connection with kiddos virtually through sudoku, coloring, puzzles, interactive activities.	
Lesson Plan 3 -Transverse Waves Delivery -Fully virtual	Bella	Student has opportunity to develop own lab, inquiry based.	Sentence stems provided for diverse learners. Easily accessible lab by using materials around house.	
Lesson Plan 4 -Transverse Waves Experimental Design Delivery -Fully virtual	Bella	Different modalities provided (video, images)		Provides only one way to show understanding with CEA (claim, evidence, analysis).
Lesson Plan 1 -Boyle's Law Delivery -Hybrid	Sally	Interactive help to solve chemistry problems. Key provided for information needed (color coded). Formula provided on top of worksheet.		-Did not see evidence of allowing student to be driver of inquiry.

<u>Lesson Plan 2</u> -How to use Schoology <u>Delivery</u> -Fully virtual	Sally	Interactive video showing how to use Schoology- color coded. Provides different modalities- videos and practice problems.		

Adapted from *Qualitative Data Collection Tools* by Felice D. Billups

Appendix G

VERBAL CONSENT SCRIPT

Introduction
I am Amy Vo, a PhD student in the Department of Teaching and Learning Sciences at the University of Denver.

I obtained your contact information from…
1. The Teacher Education Program at the University of Denver.
2. Science Education Acquaintance
2. If snowball technique, provide the name of the person who referred them.

Subjects Rights
Your participation in this research study is completely voluntary. You can withdraw at any time. Choosing not to be in this study or to stop being in this study will not result in any penalty to you or loss of benefit to which you are entitled.

Description of the study and study procedures
I am conducting a research study to study the effects of the COVID-19 pandemic on science teacher's pedagogical choices.
The name of the study is *Science Teachers' Pedagogical Judgment during the COVID-19 Pandemic*. The IRB Project Number is 1925958-1. The person in charge of the study is Amy Vo.

If you agree to participate, you will be asked to describe your teaching experiences during the previous two years of the pandemic by answering some open-ended interview questions via phone or Zoom conference call.

Risks
Your participation does not involve any risks other than what you would encounter in daily life.

Benefits
Taking part in this study may help researchers to better understand the effects of disrupting life events on science teacher's choices in the classroom.

Financial Information

Participation in this study will involve no cost to you. You will not be paid for participating in this study.

Confidentiality
Study records that can identify you will be kept confidential by removing an identifying information from the data collected and using password protected storage devices for study related data.

The results of the research study may be published, but your name will not be used.

Whom to contact with questions:
If you have any questions or problems during your time on this study, you should contact Dr. Brette Garner email: Brette.Garner@du.edu ph: 513-884-2274

If you have any questions regarding your rights as a research subject, please contact the the University of Denver's Institutional Review Board (IRB) Office at (303)871-2121

Consent Section
Do you wish to participate?
Record Subject's response: Yes No

_____ _____
Name (printed) and Signature of Person Obtaining Consent Date

If you would like a copy of this letter for your records, please let me know and I will email you a copy.

Would you like documentation linking you to this research study?

_____ _____
Name (printed) and Signature of Subject Date

Appendix H

Qualtrics Survey Inquiry Responses

Think about your own teaching pedagogy in reference to the questions below. It is not necessary to have taught the subject matter or grade. Given the possible responses how would you teach the lesson. Please provide a rationale for your choice.

The bolded phrase in italics after each response details the type of teaching style employed using the POSTT scheme by Schuster et al., 2017.

10. Frog dissection 1

Mr. Goodchild is doing a frog dissection with his 10th graders to help teach them about anatomy. Thinking about how you would teach a lesson, of the following, which is most similar to what you believe is the best way to incorporate a dissection into a lesson?

e. It should be used as a stand-alone step-by-step activity for students to explore the frog's anatomy and raise discussion questions on their own. ***Open Inquiry***
f. It should be used as a follow-up step-by-step student activity after Mr. Goodchild explains exactly what students will need to notice about the frog anatomy. ***Active Direct***
g. It should be used as a step-by-step student activity while answering probing questions, followed up by teacher-led discussion and clarifications. ***Guided Inquiry***
h. It should be used as a step-by-step demonstration by Mr. Goodchild while he explicitly points out what students need to know about frog anatomy. ***Didactic Direct***

Anna's Response:

c. Guided Inquiry: *I would potentially be somewhere between a and c. I may not be comfortable with students being completely self-led and would want to have some probing questions, while allowing students to explore and also formulate their own questions.*

Bella's Response:

a. Open Inquiry & c. Guided Inquiry *To start the year I would choose C to show students how labs in science can be used as opportunities to connect learning to real life by offering more scaffolding around how to make this happen. After a few labs with scaffolding in place to show them what I expect as far as questions, exploration, and discussion I would put the work on them and use method A. After teaching I've learned that kids need to be shown how to do the higher-level thinking before you throw them in*

because it's a new way of learning for most of them. Once they are more used to doing the higher level thinking they gain better understanding through inquiry-based activities and it sticks with them longer.

Carol's Response:

c. Guided Inquiry: *I have found that students in the 10th grade do not easily come up with discussion questions on their own, and therefore would provide the questions. It would help them make appropriate observations.*

Ray's Response:

c. **Guided Inquiry**: *Having a forum for discussion and question asking is important in my lesson plans, not simply doing a lab but having a cohort to talk about it with as a group.*

Sally's Response:

c. Guided Inquiry: *As scientists we don't always know what we are looking at the first time we see it. We have to use our past knowledge and connect the dots to make new assumptions. Giving the answers up front makes a task less exciting. I prefer to wet the students' appetites and not always give them all the answers right away.*

Seth's Response:

a. Open Inquiry: *I believe that dissection needs some direction, so there needs to be some direction for students to follow as they have most likely not completed a frog dissection. However, I do not think the lab should be a stand-alone activity as it should relate to what students are learning about organ systems, anatomy, and physiology. For this reason, even though I chose option a, I would incorporate components of option b that relate the dissection to what students are learning and have some prepared questions and follow-up discussions as included in option c.*

11. Soil porosity

Ms. Cubbage's 7th grade science class has been learning about soil types by observing soil color and texture (particle size). While making observations of soil samples, the students notice that some soil types seem more "fluffy" than others. Ms. Cubbage realizes that her students are referring to *porosity* (how densely the materials are packed together, ability to allow water to move through) which is one of the key concepts later in her unit.

Thinking about how you would teach this lesson, of the following, which is most similar to how you would respond to the students' observation?

e. I would congratulate the students on such a good observation, then explain to them *porosity* is a description of how densely packed soils are. I would then tell students how to test soils for it and follow up by doing tests on our soil samples for porosity. ***Active Direct***

f. I would congratulate the students on such a good observation and ask them what they thought they were looking at. Through discussion I would try to get them to think about packing and how one might test for packing. We would do tests and based on their findings; I would introduce the concept of *porosity*. ***Guided Inquiry***

g. I would recognize that what is most important here is that the students were being independent investigators, not necessarily that they were stumbling upon the idea of *porosity*. I would simply encourage their scientific attitudes and have them continue their investigations. ***Open Inquiry***

h. I would congratulate the students on such a good observation, then explain to them that what they observed was called *porosity*. Using a demonstration, I would show the students that more porous soils are less packed, and that water moves more easily through porous soils. ***Didactic Direct***

Anna's Response:

b. Guided Inquiry *b would be the ideal situation. Time constraints are always an issue, so I'm not sure how much time we'd have to investigate.*

Bella's Response:

b. Guided Inquiry *I would use B to help them see that science is about being curious and to help them connect observations to science concepts. This is a better option for student learning because they are "discovering" the concept themselves rather than me just telling them what it is. The creation of the test could be more scaffolded at the beginning of the year and slowly they could start to build more independent tests.*

Carol's Response*:

This one is the closest. I think that I would lead the discussion more in the direction of what quality of the soil would be affected by its porosity. And why is that important? (a, b, c, or d were not chosen)

Ray's Response*:

Did not respond to this question.

Sally's Response:

b. Guided Inquiry *This one was hard to choose between b and c. I like the idea of independent investigators, but I also think it is good to eventually teach vocabulary. Part of communicating with other scientists is understanding what they are talking about, and you can't really do that if you don't know what the big words mean.*

Seth's Response:

b. Guided Inquiry: *Option b would most closely resemble my response. I would want students to explore and come up with different ideas that we could discuss. When the time is right, I would introduce the appropriate vocabulary to help students explain their findings.*

12. Ms. Baker is teaching her 8th grade students the law of reflection: when a ray of light strikes a mirrored surface, it leaves at the same angle as when it arrived. Ms. Baker has to decide how she will teach the lesson. Thinking about your own teaching, of the following, which is most similar to how you would teach the lesson?

- **e.** I would write the law of reflection on the board and illustrate with a diagram. Next, I'd show them a real example, using a light ray source, mirror, and protractor. Then we would discuss any questions the students might have. ***Didactic Direct***
- **f.** I would ask students to find out what they can about light behavior around mirrors by exploring on their own with an assortment of available items, including light ray sources, mirrors, and protractors. Then the students would report back on what they did and what they found out. ***Open Inquiry***
- **g.** I would first pose a question about reflection for the students to explore. The students could investigate using light ray sources, mirrors, and protractors, and then discuss their findings. I would close the lesson by giving them a summary of the law of reflection. ***Guided Inquiry***
- **h.** I would write the law of reflection on the board and illustrate with a diagram. Then I'd have the students verify the law using light ray sources, mirrors, and protractors. We would then discuss their findings. ***Active Direct***

Anna's Response:

d. active direct *b and c are idealistic, but most often I would use method d.*

Bella's Response:

c. Guided Inquiry *Giving students a more clear direction of inquiry helps them stay on topic better than just telling them to explore. This option still allows discovery and creative thinking, but focuses their time use to reach the end goal. I did this with the concept of a one-way mirror and had them explore why you could see through on one side but not another. Having a guiding question allowed them to get to the concept I needed them to grasp for the standard.*

Carol's Response:

c. Guided Inquiry *This works really well with a paper protractor and laser pen. I would want them to understand what the question is, then find the answer themselves by experimenting.*

Ray's Response:

b. Open Inquiry *B is the most similar to my own lesson plan for teaching reflection. The only difference is that I give them a problem to solve (hit this target on the board without aiming your laser directly at it), but the rest would be up to them to build ray diagrams and drive the discussion on what they observed.*

Sally's Response:

b. Open Inquiry *Often in my teaching style we would begin the unit with a lab. I would let students explore and we would talk about what they learned. I would ask probing questions, but I wouldn't always tell them the answer. I would hint that we would learn about what caused this phenomenon later in the week. Then when we did learn about it, I would refer back to the lab and ask, "What part of the lab matches this scientific concept?"*

Seth's Response:

b. Open Inquiry *I would choose option b to allow students to first have experiences and begin to form ideas about light. We could then discuss the characteristics observed, attached vocabulary, and formulate laws about light.*

*****Carol and Ray did not respond to Question 2 because the Qualtrics Survey had malfunctioned and was not providing the multiple-choice options.