The Pandemic Dilemma: A Mixed-Methods Study of Student-Centered Science Education in the COVID-19 Pandemic

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The Pandemic Dilemma: A Mixed-Methods Study of Student-Centered Science Education in the COVID-19 Pandemic

A Dissertation

Presented to the Faculty of the

College of Education and Social Work

West Chester University

In Partial Fulfillment of the Requirements for the

Degree of

Doctor of Education

By

Jennifer L. Slavick

March 2021

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Dedication

This dissertation is dedicated to three generations of my family. To my grandfather, Robert A. Korecky, who spoke to me early and often about academic achievement and how important knowledge is. I wish he could be here to watch me defend the knowledge I have produced, but whom I know would be intensely proud of the work I have put forward. To his daughter, my mother, Linda, who inspired in me a lifelong curiosity and love of learning and has been here every step of the way. Finally, I dedicate this work to my girls, Evelyn and Gillian. May they see this and know what women can do.
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I would also like to thank my family, who have listened to me prattle on at length about what I’m learning in class and what I’m writing about. Mom, thank you for all the time you’ve dedicated to talking with me about the work I’m doing. I have enjoyed our phone calls and am grateful for how you have listened when I am stressed and helped me see the forest for the trees. I am also grateful for the ways in which you prepared me to conquer this task. You’ve always encouraged me to tackle anything and built me into the strong person I am today.
Finally, I would like to thank my husband, Matt. You have been with me through two degrees and I can’t believe you agreed to support me through this one. Thank you for encouraging me to pursue knowledge for knowledge sake and understanding me as a human. Thank you for all of the evenings you spent with our girls so I could go to class, for all of the early morning coffees while I was too tired to get up, for being the rock our family needed while I traveled the country to collect and analyze this data, and for all of the time you gave me and work you picked up so I could focus on producing this. Your support has meant more than anything to me and I am forever grateful.
Abstract

The purpose of this explanatory sequential mixed-methods study was to determine how student-centered instruction shifted and what dilemmas teachers experienced in enacting science instruction as they worked through the COVID-19 pandemic. A modified Draw-A-Science-Teacher-Test was used to examine teachers’ perceived instruction during the Fall of 2019, Fall of 2020, and Fall of 2021. Scores on this modified checklist were compared to determine differences in instruction year-to-year, across grade-bands, and to find trends in instruction concerning student demographics. Interviews were conducted with a subset of teachers in the study to learn more about the dilemmas they faced as their attempted science instruction. Results indicate that teachers’ perceived instruction was mostly student-centered in the fall of 2019 and became significantly teacher-centered in the fall of 2020. Further, teachers’ perceived instruction shifted back toward student-centered in the fall of 2021 but had not reached pre-pandemic levels at that time. Further, teachers that were interviewed recalled being impacted by a variety of dilemmas during each timeframe, including conceptual, pedagogical, cultural, and political dilemmas. Most interestingly, teachers experienced a unique existential dilemma during the pandemic, which I call the pandemic dilemma, that could impact science education in the future.

Keywords: science education, dilemma, student-centered, COVID-19
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Chapter 1 – Introduction

In “A Call to Action for Science Education: Building Opportunity for the Future,” the National Academies of Sciences, Engineering, and Medicine (2021) state:

Over the past 15 months, Americans have had delivered to them a powerful message about why science is essential to the well-being of the United States. The rapid development of COVID-19 vaccines was a 21st century moonshot. We have seen firsthand why science is a powerful public good that we must preserve and prioritize (p. 11)…A big mistake the country has made is believing that science is for scientists only. Science should be taught with all people in mind, not just to fill the pipeline for future scientists and technical workers. The nation’s schools teach reading, writing, and mathematics because these are foundational skills for daily life and participation in society. Science literacy is fundamental as well. (p. 14)

As a science teacher and then as a science teacher leader, these words from the Call to Action mirror the drive I felt when working to better the state of science education in the schools and systems in which I worked. For myself, I have worked hard over many years to learn to center my students, their questions, and their ideas in my own classroom. I regularly utilized three-dimensional instruction in my own classroom and worked to improve my practice in this area. Through trial and error, I learned to teach science by weaving together three dimensions: disciplinary core ideas (traditional content), crosscutting concepts (overarching themes, abbreviated CCs), and science and engineering practices (formerly the scientific method, abbreviated SEPs) (NGSS Lead States, 2013). When I entered teacher leadership through my assistant director position and later as a consultant, I taught others how to center students and incorporate the three dimensions of the Next Generation Science Standards (NGSS) into their own instruction.
In my own experience, teachers embraced the science and engineering practices, at least some of the time, and at varying degrees across grade levels. However, we worked together to improve their teaching practice and I worked to improve my professional development practice. Across the science education community, three-dimensional instruction became more refined. Now, the use of relevant phenomena and incorporating sense-making practices that center students epistemologically are the hurdles that have proven even more challenging than incorporating the SEPs and CCs for the teachers I work with. For me, and likely many others, these teaching practices became even more difficult during the COVID-19 pandemic.

As schools shut down and I lost my work consulting, I returned to the classroom. I worked with a school to launch their science program, which involved teaching to 400 kindergarten through third grade students science via computer. It was time for me to put my preaching into practice. I began my work with lofty expectations – to engage my students with relevant phenomena, with as many hands-on materials as possible, and deeply. I quickly ran into roadblocks, however, like supplying students with materials; keeping them engaged for the entire class; and getting them to communicate with each other. This task proved more challenging than I ever could have imagined. This dissertation seeks to tell the story of the dilemmas that science teachers face when enacting student-centered science and to document that journey as teachers persevered through the COVID-19 pandemic.

**Rationale**

The 1996 National Science Education Standards were the first standards to be published regarding science education and were born out of the policy report *A Nation at Risk* (National Commission on Excellence in Education, 1983) and the subsequent *Benchmarks for Science Literacy* (Project 2061, 1993). The purpose of science education espoused in these standards is
three-fold: personal fulfillment and excitement, informed decision making, and finding meaningful and productive employment (National Research Council (NRC), 1996, p.11). Years later, the Framework for K-12 Science Education (2012) shared the same goals (NRC, 2012, p. 7). However, the most recent Next Generation Science Standards (2013) reversed these goals, where increasing the STEM workforce and providing economic benefits to the state were primary and personal scientific literacy, enjoyment, and informed citizenship were secondary (NGSS Lead States, 2013, p. XV).

These themes reiterate the two major dichotomies in the purpose of education through modern formal curricular history (Pinar et al., 1995). Increasing student performance in science as a means of serving economic interests of the state leans strongly toward the social efficiency ideology; increasing student performance in science so students can make informed decisions and interpret the world around them leans toward the child-centered ideology. Either way, a move away from strong science education impacts our students’ ability to be informed and engaged citizens as well as their ability to contribute to our scientific workforce. Therefore, it is important to understand the impact COVID-19 has had on science education and how lasting that impact will be.

**Purpose**

The purpose of this study was to determine how science teachers and their instruction were impacted because of the effects of COVID-19 on school systems. The study quantified how student-centered teacher practice was before the pandemic and compared that to how student-centered it was following the onset of the pandemic. Further, teachers’ lived experiences were captured through interviews. The goal of the interviews was to understand what dilemmas teachers faced while trying to enact strong science instruction. While several methods exist to determine which NGSS practices teachers were using, this study focused on how student-
centered teachers believe their science instruction was and what barriers existed to maintaining this student-centered approach.

Research Questions

The primary question addressed in this study was, in what ways did perceived student-centered science instruction change while the education community was experiencing a pandemic? Embedded within the primary question were two sub-questions:

1. What was the extent to which teachers’ perceived science instruction was student-centered over a three-year time period, considering socio-economic status and racial composition of the school system?

2. What were dilemmas faced by teachers of student-centered science classes through the pandemic?

A Brief History of Science Instruction

Science instruction has shifted in the past decade with the release of the Framework for K-12 Science Education, published in 2011 (hereafter referred to as the Framework) and the subsequent Next Generation Science Standards, published in 2013. The previous science standards, 1996 National Science Education Standards, placed student-centered and inquiry-based instruction at the center of science education strategies, but the Next Generation Science Standards developed those ideas even further.

The Framework and NGSS went a step further in advancing the science education agenda by intentionally considering strategies to improve access to and equitable instruction of science for historically marginalized populations. It is the view of the authors of the Framework and NGSS that marginalized populations should experience greater access to strong science education so students can engage in public discussions, become careful consumers of technology, and learn about and engage with science outside of the school environment (National
Research Council, 2012). The authors of the NGSS hoped to accomplish this vision by proposing teachers engage students with relevant phenomena that students could make sense of with robust conversations and argumentation from evidence collected in the classroom. Teachers should further incorporate engineering into regular instruction so all students could see the application of the science ideas they are working on in the classroom. The authors of the NGSS formed a diversity and equity team to research and suggest specific strategies to engage seven specific populations of historically marginalized students, which included: students from economically disadvantaged backgrounds, racial and ethnic minorities, students with disabilities, English language learners, girls, students in alternative education, and gifted and talented students (NGSS Lead States, 2013; Lee, Miller, & Januszyk, 2014).

As the authors of the Framework discussed, increasing student participation and success in science is important for their personal fulfillment (National Research Council, 2012). Student success is often measured in achievement scores on high stakes tests, and students from low socioeconomic status (SES) backgrounds and minority students are more likely to demonstrate an achievement gap in science on standardized tests (Emmer, 2018). This achievement gap can be due to many issues, including an increased focus on math and literacy (Johnson & Fargo, 2014), decreased funding for science supplies (Gorard, 2016), inexperienced teachers (Clotfelter, Ladd, & Vigdor, 2010; Sandholtz & Ringstaff, 2013), and the use of inappropriate instructional strategies in the classroom (Akerson et. al., 2009).

Teacher choice of instructional strategy in the science classroom can be influenced by many factors including teacher preparation (Akerson et. al., 2009), identity (Chen & Mensah, 2009), content knowledge (Sandholtz & Ringstaff, 2013), and teacher beliefs about their students (Bryan & Atwater, 2002). Bryan and Atwater (2002) demonstrated that teachers commonly
believe that culturally diverse students are less capable, less motivated, and have less emotional
and physical control than their white peers. Teachers may also believe that parents of culturally
diverse and low socioeconomic students are less engaged with and less supportive of education
than their white peers. These biases lead teachers to provide more rigid and structured
classrooms and lower cognitive demand tasks (Bryan & Atwater, 2002), which is the opposite of
the recommendations of the NGSS and culturally responsive instruction associated with teaching
in a diverse classroom (NGSS Lead States, 2013).

While science instruction reform has consistently moved toward centering all students
epistemologically, there is little information regarding how often this approach is occurring in
classrooms. Further complicating matters, the world experienced a global pandemic in 2020 that
forced changes in instruction across the board. Challenges were variable across contexts and
school populations, with urban and high-poverty schools challenged the most (US Department of
Education Office for Civil Rights, 2021). Teachers received little training in switching
effectively to remote instruction. Further, finding ways to effectively replace hands-on
instruction and engage students were the top two instructional needs teachers reported
(Hamilton, Kaufman, & Diliberti, 2020). All these challenges likely impacted science education
best practices and may continue to do so for some time.

Significance of Methods

This study utilized a mixed-methods approach for data collection and analysis. Creswell
and Plano-Clark (2018) wrote that mixed methods should be used when, “the complexity of our
research problems calls for answers beyond simple numbers in a quantitative sense or words in a
qualitative sense” (p. 23). Because correlation does not mean causation, I was unable to use
statistics alone to show that disruptions from COVID-19 to the education community caused a
shift in teacher practice. Therefore, it was important to include qualitative data to examine the
exact factors that impacted teacher practice. Further, simply showing in numbers how student-centered teachers believed their science classrooms were over time cannot help us unpack the challenges teachers faced when planning and executing their instruction. Without that data, the research will not be usable to help get science instruction back on track if it has gone astray. Therefore, quantitative data in this study was collected via survey and the quantitative data was augmented and compared to qualitative interviews that shed light on the realities of execution.

**Quantitative Data Collection**

Surveys and questionnaires are a convenient way to collect information from a sample population that is spread across a wide geographic area (Creswell & Guetterman, 2019). The Draw-A-Science-Teacher-Test-Checklist (DASTT-C) comprised the core of the survey instrument (Thomas et al., 2001) to address the student-centered nature of instruction during the pandemic. In this instrument, participants from the National Science Teaching Association were asked to draw three pictures of their science classroom, including the teacher and the students, one for each of the ’19-’20, ’20-’21, and fall of 2021 school years. Teachers were asked to write a brief explanation for each drawing describing what the teacher was doing and what the students were doing in the drawing. The drawings were then coded using a checklist and the score was tallied to determine the “level” of student-centered instruction teachers perceived was occurring in the classroom. While the DASTT relies on teachers’ drawings of their classrooms and is grounded in teachers’ perceptions of their own practice, Haney et al. (2004) showed how drawings are a valid tool to use to document educational phenomena in practice in the classroom, linking perceptions with actual practice.

The survey data was coupled with demographic and socio-economic information about teachers’ schools, which was gathered from the National Center for Education Statistics.
Gathering this data helped illuminate the nuances in science instructional practices for students living in all sects of the United States. To analyze trends in the data, a repeated measures ANOVA was used to compare the mean scores from the DASTT for year-on-year trends. A one-way ANOVA was used to examine within grade-band and then across grade-bands for each year. A Pearson correlation was used to show the relationship between socioeconomic status of the school or racial composition of the school and teacher practice. Previous research has gathered information about pandemic science instruction, but the study sample was based almost entirely in California, representing only a small geographic sample of science teachers (Iveland et al., 2021). This current study sought to gather a more complete understanding of teaching practices across the United States, a geographically wide-ranging population.

**Qualitative Data Collection**

Because one of the sub-questions focused on the lived experiences of teachers, this study used a multiple case study that focused on individuals at different sites across the country. Recent literature in the science education field is dominated by case studies (Braaten & Sheth, 2017; Chen & Mensah, 2018; Haverly et al., 2020; Kang & Zinger, 2019; Mangiante, 2018; Wei et al., 2019). Therefore, there is a well-documented history of case study in this field that lends credence to the approach for this study. Further, Mark et al. (2019) conducted a multiple case-study to describe the lived experiences of pre-service teachers in culturally diverse settings and Cherbow et al. (2020) used a multiple case study approach to understand what science instruction looks like in different locations as well as how the system surrounding teachers impacts their instructional decision-making. This current study proposed to understand teacher lived experience and how systems impact teacher instructional choices, making a multiple case-study very appropriate. Finally, Braaten and Sheth (2017) utilized a case-study approach to
understand how dilemmas were experienced by an educator, further illuminating how the theoretical framework can be applied in this study and with this approach.

**Significance of the Study**

WestEd, a nonpartisan and nonprofit agency based in California, has begun a study of the impacts of COVID-19 on science instruction and the enactment of the NGSS in science classrooms (Iveland et al., 2021). This study is ongoing and began in the spring and summer of 2020. My doctoral thesis expands on this work. Like the present study, the WestEd study seeks to know how teaching and learning has changed over time and how the pandemic played a role. However, their sample was grade 6-8 classrooms and more than 70% of their study population originated in California. Also similar to the present study, WestEd did not focus on specific NGSS practices. The study has a slightly different lens than this present study did as they recorded data on time spent in science classrooms, modalities of delivering instruction, student discourse, and investigation-related practices. The present study adds to the science education community’s understanding by broadening the study population and incorporating qualitative interviews to more deeply understand the nuances of teacher experience, especially taking into consideration the role of the systems surrounding the classroom.

**Definition of Terms**

*Dilemmas* are the situations that challenge teachers when they try to enact student-centered instruction in the science classroom. “‘Dilemmas’ are aspects of teachers’ intellectual and lived experiences that prevent theoretical ideals of constructivism from being realized in practice in school settings” (Windschitl, 2001, p. 132).

*A Framework for K-12 Science Education* is a publication by the National Research Council that utilized the existing science education literature to lay the foundation for the most recent revision of the national science education standards in 2012. “The Framework highlights
the power of integrating understanding the ideas of science [DCIs] with engagement in the practices [SEPs] of science and is designed to build students’ proficiency and appreciation for science over multiple years of school: (National Research Council, 2012, p. x).

Next Generation Science Standards are the current nationally recommended science standards that were published in 2013 based on the ideas outlined in the Framework for K-12 Science Education (NGSS Lead States, 2013).

Student-Centered Instruction is “a form of active learning where students are engaged and involved in what they are studying” (Brown, 2008, p. 30). The Next Generation Science Standards and the focus on students’ questions about phenomena and sense-making therein create a partnership where the teacher and student are working with each other to determine the goals and meaning of the science work (Neumann, 2013). Bremner’s meta-analysis showed that truly student-centered instruction required six components: active participation of the student, a focus on relevancy (phenomena), adapting to student needs, power sharing between the teacher and student, autonomy of the student, and formative assessment throughout the process (Bremner, 2021).

Limitations

There are several limitations or ethical considerations for this proposed study. First, the population of teachers being studied comes from an organization of highly motivated science teachers as evidenced by the fact that they choose to pay and belong to a professional organization of science teachers and to find a way to come to a conference during a global pandemic. It is also possible that teachers in this population are more likely to be using student-centered instructional practices because they are more aware of shifts in science education and have had more professional development through their involvement with the organization.
However, the National Science Teaching Association is likely the most representative population when thinking about capturing information on a national level, so the trade-off in data acquired is still valuable.

Second, there are issues of generalizability in this study. The sample sizes of the quantitative and qualitative portions of the study are uneven, possibly leading to skews in the data analysis and conclusions (Creswell & Plano Clark, 2018). It will be important for the researcher to carefully consider what conclusions can be made from the mixed-methods data.

A third limitation is that the Draw-A-Science-Teacher-Test is clearly grounded in teachers’ beliefs and perceptions of their work (Thomas et al., 2001). While there is evidence that teacher drawings of their practice are a reliable indicator of what is happening in the classroom (Bishop, 2006; Gulek, 1999; Haney et al., 2004), and the authors of the DASTT used the tool to compare in-practice teachers’ styles to student perception of scientists (Finson et al., 2006), firmly linking the DASTT to actual practices of teachers, some caution must be exercised about what the tool can actually say about what is happening day to day in the classroom. For that reason, caution was exercised here in interpreting the results of the study, framing the events as teachers’ perceptions of their practice.

Finally, racial demographic data was used during data analysis in this study. School systems must report their demographic data to the government for a myriad of funding requirements. As such, schools and families are asked to identify their children’s racial and ethnic origins to the government. It is widely understood that identity and race are incredibly complex constructs (Roberts, 2011). This study is limited by the data that is reported on the federal website in that there is no way to guarantee the method used to require families to identify with a race or ethnicity.
Summary

Science education has undergone a significant pedagogical shift in the last decade. In the last two years, a global pandemic has disrupted education across the globe. This study captured the disruption in the student-centered nature of science instruction via both a quantitative survey and qualitative interviews with teachers who experienced the disruption. While there are some limits to the generalizability of the results, I was able to explore the dilemmas teachers faced. The next chapter in this dissertation will discuss the theoretical framework used for the study as well as literature demonstrating the dilemmas teachers faced while enacting student-centered science instruction before the COVID-19 pandemic.
Chapter 2 – Theoretical Framework and Literature Review

The story of science education over time is the story of a long push to center students in the classroom. Since the development of the National Science Education Standards (National Research Council, 1996), which called for an inquiry-based approach, to the most recent Next Generation Science Standards (NGSS Lead States, 2013), which calls for centering students epistemologically by engaging them with relevant phenomena and the practices of science, the science education community has demonstrated its commitment to constructivist learning and a student-centered approach. However, the goal of universal student-centered instruction has not yet been realized. As recently as 2017, teachers were reporting only “sometimes” using investigation-related practices in their classrooms (Iveland et al., 2021). This is only complicated by trying to teach through a global health crisis. So, what is causing practice to fall apart?

The challenge in science education does not revolve around a disagreement about how teachers should be teaching science. The widespread adoption of the NGSS demonstrates that most policy leaders are in agreement with the approach espoused in the standards. The challenge, then, becomes execution of this vision. We cannot, as a community, remove the barriers to achieving this vision if we do not understand them. This chapter will focus on Windschitl’s Dilemma Theory as the theoretical framework for the tensions experienced by science teachers and the science education community. While exploring the “conceptual dilemma” portion of Dilemma Theory, I will discuss the current arguments about the definition of true student-centered instruction. Finally, I will explore current research that shows how Windschitl’s Dilemma Theory is experienced in the field. Finally, I will relate the framework and literature to the current reality of teaching during a pandemic and set the stage for the methods used in the study.
A Theoretical Framework for this Study: Windschitl’s Dilemma Theory

The current iteration of science education espoused by the Next Generation Science Standards is intended to occur “with” students and is complex to execute in practice. Studies show that preservice teachers hold more student-centered beliefs than in-service teachers, implying something happens in the execution of the work (Neumann, 2013). In 2001, Mark Windschitl offered a framework to explain all the factors that influence the execution of student-centered science instruction. Table 2.1 shows the components of Windschitl’s theory.

Table 2.1

Tenets of Dilemma Theory

<table>
<thead>
<tr>
<th>Conceptual Dilemma</th>
<th>Pedagogical Dilemma</th>
<th>Cultural Dilemma</th>
<th>Political Dilemma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep understanding of constructivist theory</td>
<td>Working harder to make student centered instruction happen</td>
<td>Traditional classroom culture expectations</td>
<td>External curriculum</td>
</tr>
<tr>
<td>Distinguishing which theory is used</td>
<td>Including preconceptions of students</td>
<td>Teacher learning history</td>
<td>Basic skills focus</td>
</tr>
<tr>
<td>Reconciling own epistemology with constructivist epistemology</td>
<td>Facilitating thinking and sensemaking</td>
<td>Student learning history</td>
<td>Standardized testing</td>
</tr>
<tr>
<td></td>
<td>Planning for student choice</td>
<td>Cultural frames of reference</td>
<td>Parental input</td>
</tr>
<tr>
<td></td>
<td>Navigating discourse</td>
<td></td>
<td>Leadership directives</td>
</tr>
<tr>
<td></td>
<td>Requires deeper content knowledge</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Windschitl’s (2001) dilemma theory in constructivist classrooms pre-dates the Next Generation Science Standards, but still clarifies the complexities of the systems impacting teacher practice. Windschitl (2001) wrote:
Classroom teachers are finding the implementation of constructivist instruction far more
difficult than the reform community acknowledges…In addition to providing a unique
theoretical perspective for researchers, [this] framework is a heuristic for teachers,
providing critical questions that allow them to interrogate their own beliefs, question
institutional routines, and understand more deeply the forces that influence their
classroom practice. (p. 1)

The first dilemma constructivist teachers face is a conceptual dilemma. Teachers must
come to a deep understanding of what constructivism and student-centered means in the science
classroom and believe in the practice itself. Teachers struggling with a conceptual dilemma tend
to practice teaching that is more direct than exploratory. To counter this, teachers must also
grapple with their own epistemological beliefs. This grappling can often be the most challenging
to overcome. Windschitl (2001) notes:

Even teachers who explicitly profess a constructivist epistemology often find themselves
drawn back to more familiar recitation scripts. Tobin (1993) describes Rod, a high school
teacher, who claimed that he maintained a constructivist epistemology and yet found
himself inextricably bound to teacher-centered routines in which he solicited correct
answers to convergent questions, provided immediate feedback on the adequacy of
student responses, and searched for students who could provide correct answers to his
questions. (p. 143)

Once teachers embrace the theory of constructivism, “teaching with a constructivist lens
requires far more work than traditional classroom instruction, which presents pedagogical
dilemmas” (Cohen, 1988, p. 255). For students to confront their preconceived notions, teachers
must be fully aware of what students believe or understand at every moment. This requires more
work on the part of the teacher by incorporating and facilitating student reflection and revision of ideas over time. Further, because every student may be entering the classroom at a different place in their conceptual understanding, constructivist teachers must plan multiple avenues for students to choose to facilitate their thinking. This represents a significant increase in the number of lessons a teacher must plan. These pedagogical needs demonstrate why these dilemmas may prove challenging for teachers to surpass and push teachers to choose a more teacher-centered approach (Windschitl, 2001).

If teachers can move past their own conceptual and pedagogical dilemmas, they may then encounter cultural dilemmas both within the classroom and personally. In the classroom, constructivist teaching looks quite different than traditional classrooms in practice. Students are given more epistemic agency and the role of teacher and student shifts. This may present a dilemma for both the teacher and the student. Teachers must confront their own learning histories, creating new patterns in their understanding of how classrooms should be culturally than what they themselves experienced. Students also must confront their own learning histories and learn to embrace empowerment and uncertainty. Teachers who struggle with classroom management may struggle with a cultural dilemma. Personally, cultural frames of reference that differ between the teacher and the student population due to their own social identities may present dilemmas in understanding and valuing ideas in the science classroom (Windschitl, 2001).

Political dilemmas arise when teachers face challenges from outside of their classroom. These challenges come in many forms. First, the adoption of curriculum or textbooks that espouse a “mile-wide” approach to science force teachers to choose between the deeper and more focused constructivist approach and the need to “cover it all.” Second, a focus on basic
skills and standardized testing is at odds with a constructivist approach in the science classroom. Further, the emphasis on math and literacy in standardized testing leaves little room in the day for the time it takes to enact constructivist science pedagogy. Finally, teachers must justify constructivist teaching practices to parents, who likely were not taught in a constructivist science classroom and can have a large effect on school board and principal decisions when it comes to instruction (Windschitl, 2001). Figure 2.1 demonstrates how Windschitl’s dilemma theory causes shifts in Neumann’s continuum of teacher practice.

**Figure 2.1**

*Windschitl’s Dilemma Theory Impacts Neumann's Student-Centered Continuum*

The complexities of successful student-centered science education were clear before adding the challenges of a global pandemic, which severely disrupted education across the United States and the globe and likely heightened the dilemmas teachers faced. This study seeks to understand the magnitude of the disruption to student-centered science instruction through the pandemic as framed by these two constructs.
Tackling the Conceptual Dilemma: What is Student-Centered Instruction and How Does It Relate to the Next Generation Science Standards?

How humans, and more specifically, children, learn best, has been a debate at the center of education throughout time (Pinar et al., 1995). That debate is carried through modern day education and can be seen clearly through the lens of science education standards. Learning theories in science have developed over time and lead to two common models of science instruction: direct (or teacher-centered) instruction and inquiry-based (student-centered, constructivist) instruction (Agarkar & Brock, 2017). Since the National Science Education Standards were published by the National Research Council, hereafter referred to as the NRC, in 1996, inquiry, or reform-based instruction, has been a focus in the science education community (Eick & Reed, 2002; NRC, 1996). The practices that were espoused in the standards represented a significant shift in the practices of most science educators, namely from teacher-centered instruction to student-centered instruction.

In the early 2000’s, new policy documents such as America’s Lab Report (NRC, 2006), Taking Science to School (NRC, 2007), Ready, Set, Science! (NRC, 2008), and Learning Science in Informal Environments (NRC, 2009) illuminated further shifts needed in science education (Lee et al., 2014). As a result, in 2012, the National Research Council published the Framework for K-12 Science Education (hereafter referred to as the Framework). The Framework calls for teachers to instruct students by continuing inquiry-based instruction as well as incorporating 3-Dimensional learning, integrating the Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. Engineering was also incorporated as a core part of the new Framework. This integration ensures that students are generating their knowledge from authentic
experiences, working and thinking like scientists, and allows students to apply their understanding more completely to novel situations (National Research Council, 2012).

Following publication of the Framework, a 41-member writing team was assembled from a group of 26 lead state partners (NGSS Lead States, n.d.; Rodriguez, 2015). Led by Achieve, Inc., this writing team drafted the Next Generation Science Standards (hereafter referred to as NGSS). These standards, based on the Framework itself, have been adopted in 44 of the 50 states, representing a significant shift in science education across the nation (National Science Teaching Association, n.d.). The Next Generation Science Standards incorporate the 3-dimensional learning and engineering recommended in the Framework. Additionally, the NGSS writing team further developed the use of relevant phenomena and sense-making necessary for students to be successful in science and within the world that immediately surrounds them (Haverly et al., 2020).

As the science education community shifts to adopting NGSS, it will be necessary to understand the student-centered nuances of science instruction to ensure the community is normed and practice is consistent. Incorporation of the practices espoused in the NGSS can be counted as student-centered depending on the educational framework being used to define the practice. In what follows, I will explore the philosophical foundations that have led to considerable confusion regarding what constitutes student-centered pedagogy in education. Next, I will discuss the tensions found in several prominent student-centered teaching frameworks. Finally, I will discuss the implications for this tension in my doctoral research.

**Philosophical Underpinnings Leading to Tensions in Defining “Student-Centered”**

Many philosophers have contributed to and disagreed about the appropriate way to educate students over time. These many contributions, while important in furthering our
approach toward education, have contributed to a muddying of the waters, per se, in constructivist and student-centered pedagogy. Jean-Jacques Rousseau (Rousseau, 1979) is one of the earliest modern philosophers espousing student-centered pedagogy. Rousseau believed that children learn through experiences and natural consequences of their actions. As such, the role of the teacher, in Rousseau’s view, is to provide the student with experiences and then step aside so the child can freely explore their world and learn from whatever happens. Similarly, Maria Montessori (Montessori & Claremont, 1965), believed that students learn best when allowed to engage freely with their environment. However, in contrast to Rousseau, Montessori believed that the teacher needs to have intentional pre-determined goals that the students need to meet. The teacher then provides an environment in which students can reach those goals independently through their own exploration (Pinar et al., 1995).

Dewey (Dewey, 1916) added another nuance to the learner-centered approach in education. Dewey believed that learning is social and interactive, and that the curriculum should be decided based on a combination of student interest and teacher direction (Neumann, 2013). Seemingly, Dewey split the difference between Rousseau and Montessori when discussing where the direction of the curriculum should emanate from. Just after Dewey, Lev Vygotsky posited that learners should be met at their “Zone of Proximal Development.” As such, teachers should consider what learners already know and where they are developmentally to design curriculum best suited to the learner (Pinar et al., 1995).

In the 1970’s and 1980’s, Jean Piaget built on Dewey’s constructivist foundation. Piaget believed that students learned through experience and that students needed to interact to construct knowledge. Further, learning experiences should be built on prior knowledge and experience, taking into account students’ individual experiences to design curriculum (Piaget,
1971). Around the same time, Paulo Freire added a nuance to student-centered philosophy. Freire believed that education was constructed from the experiences of the student, but when the social and political experiences of the individual were considered, the curriculum could be emancipatory and serve a liberatory purpose (Freire, 1972).

This historical account of the philosophies of student-centered education is, of course, not exhaustive of all theories that have been posited over time. However, it does demonstrate the variety of focuses of each student-centered philosophy. From free-will and open exploration, to co-constructed curriculum, to exploration with student prior knowledge as the focus, and finally to incorporating a humanistic approach, the student-centered approach has many complex parts. So, the question is, which version of student-centered approach is truly student-centered? If, as Dewey would suggest, the teacher works with the student to co-construct the topics of study, is that student-centered enough? Rousseau would argue it is not. With the rise of standardized testing and national curriculum, neither Rousseau nor Dewey would count the work of most science teachers today as student-centered, as the curriculum and goals are completely pre-determined.

**Offering Frameworks to Conceptualize Modern Student-Centered Learning**

Table 2.2 below demonstrates four current theoretical frameworks for analyzing the student-centered nature of instruction. Each framework and its major components are listed. In this section of the paper, I will briefly describe each framework and then compare them to parse out the tensions that still exist.
Table 2.2

Comparing Four Frameworks for Student-Centered Learning

|---------------|---------------------|----------------|----------------|

**Neumann’s “Contours” of Learning.** In “Developing a New Framework for Conceptualizing ‘Student-Centered Learning,’” Jacob Neumann (2013) analyzed his own teaching practices. Upon reflection and consulting the literature, he realized that different scholars would classify his teaching practices differently:

‘Student-centered’ learning contexts are perhaps most often understood in opposition to ‘teacher-centered’ contexts. As Lunenburg and Korthagen (2005) wrote, ‘teacher-
centered [learning contexts]…present information that students are supposed to take
in[,]…whereas student-centered learning is focused on helping students to develop
understanding, to build their own conceptions and knowledge.’ (Neumann, 2013, p. 162)

Neumann explained that in his course, students constructed their own understanding and
situated it in their lived experiences and context. However, students did not have any say in
course objectives, content, or course products. Therefore, the classification of his course as
student-centered by the university may have been inaccurate.

Neumann (2013) then posited a framework for evaluating teaching practice on a loose
continuum that focuses on the relationship between the teacher and the student. Neumann’s
framework built on that of Otto Bollnow (1963). Neumann’s “three contours of student-
centeredness” focused on whether the learning centers “in” students, “on” students, or “with”
students. When the learning is centered “in” students, it is focused entirely on the intrinsic
interests of the student, similar to thinking posited by Jean Jacque Rousseau (Pinar et al., 1995).
While providing deep meaning and facilitating engagement for students, learning that centers
entirely “in” students runs the risk of students learning a narrow body of knowledge and being
unprepared for life that occurs around their immediate context.

Learning that is centered “on” students is still student-centered, but heavily guided by the
teacher (Neumann, 2013, p. 166). In this contour, students have some choices within the
curriculum, but the teacher establishes the learning targets and assessments. This type of learning
is perhaps the most common approach taken in schools in the modern United States. This is
especially true when we consider the federal mandate teachers must teach to a set of standards
and that students pass minimum proficiency tests. Certainly, the adoption of national Next
Generation Science Standards forces classrooms into this contour when taken at face value.
There are criticisms of this type of “student-centered” classroom. First, complex subjects tend to be diluted into a manageable size and nuances can be lost. Second, this top-down focus on learning encourages passivity and compliance in students and they learn to “play the game” of school (Neumann, 2013).

Finally, Neumann detailed a third, middle-ground contour for a student-centered approach. This type of learning occurs “with” students. “Because students are seen as free beings, teachers enlist students in a more reciprocal learning relationship” (Neumann, 2013, p. 168). This final contour shares roots with Dewey and Freire: Dewey supplying the collaborative portion and Freire offering the humanistic portion.

NGSS espouses learning that centers with students, but is that what is actually happening in the field? This question is the focus of this doctoral study. For this, I will draw from Neumann. Neumann’s simple contours allow the classroom dynamic to be easily situated within the student-centered continuum. However, Neumann’s contours have been criticized or built upon.

**Schweisfurth: The Scope is Too Narrow.** In “Learner-centered pedagogy: Towards a post-2015 agenda for teaching and learning,” Michele Schweisfurth (2015) critiqued the national educational community and Neumann as being too narrow in their definition of what constitutes student-centered instruction, especially when considering the context within which the education is happening. The larger education community tends to adopt Western pedagogical practices may not be appropriate in some places around the globe that hold other cultural beliefs. Further, prescriptive programs for teachers discount local context. Schweisfurth (2015) noted,

This begs the question of whether a single vision of quality [student-centered] pedagogy is feasible, given the fact that pedagogy cannot be divorced from the social and resources
context in which it exists. If such a vision does exist, it would have to be based on sound principles and evidence. It would have to embrace a wide range of cultural norms which frame teaching and learning practice where they support positive processes outcomes. (p. 261)

Schweisfurth detailed numerous barriers to student-centered learning implementation across contexts such as time, resources, geography, policy, and culture. Therefore, Schweisfurth offered a set of minimum standards (engaging, mutual respect between teachers and students, builds on pre-existing knowledge, engages students in dialogue, focused on both skills and knowledge, and contains formative assessment based on learning and growth) meant to set the bar for appropriate student-centered learning while allowing for the various contexts globally. This framework seems to straddle Neumann’s “on” and “with” contours by incorporating engagement and mutual respect and has a more humanistic focus. For example, Schweisfurth detailed how a mutual respect between teachers and students in some contexts might mean co-constructing course objectives or it might simply mean that students show a culturally appropriate respect for their teacher and the teacher, in turn, respects the dignity and humanity of students (for example, by not using corporal punishment) (Schweisfurth, 2015).

**Starkey and Student Agency: A Disagreement.** In 2019, Louise Starkey performed a limited literature review to propose three dimensions of student-centered learning that could be used to guide policy and practice. Upon reviewing the literature and categorizing the priorities researchers were placing on aspects of the teacher-student relationship, Starkey proposed a cognitive dimension, an agentic dimension, and a humanist dimension of student-centered instruction as opposed to Schweisfurth’s seven categories.
Starkey’s (2019) cognitive dimension has a “focus on student learning progress” (p. 379). In this dimension, constructivism is the primary method of student learning. “An emphasis on the cognitive dimension includes teachers analyzing students’ knowledge and skills (cognitive development) to inform learning experiences that progress their learning” (p. 379). While Starkey does not reference any of Schweisfurth’s work in this literature review, Starkey’s first dimension would incorporate Schweisfurth’s minimum standards of utilizing student prior knowledge, building skills and knowledge, and utilizing formative assessment (Schweisfurth, 2015).

Starkey’s (2019) second dimension focuses on student empowerment and agency. In a constructivist frame, empowering and agency means that “students are actively participating in and aware of their cognitive development” (Starkey, 2019, p. 380). Starkey acknowledges that student agency is contested in the literature. This acknowledgement harkens back to Neumann’s 2013 framework and seems to lie at the heart of all debate surrounding student-centered classrooms: how much agency is enough to qualify instruction as student-centered?

In Neumann (2013), this debate was made clear:

In the empirical studies mentioned earlier…it is difficult to cleanly separate the centered on contour from a more traditional teacher-centered context. In each of those examples, the teacher selects, creates, organizes, and assess inquiry for students. It seems that students are simply allowed more choice and freedom within this student-centered contour than in a more “teacher-centered” context…This is a far cry from the student-centeredness of Freire and Dewey – so different, in fact, that it begs a question: Should centered on contours even be called student centered? In other words, is it a sufficient measure of student-centeredness that students have some measure of choice in how to
study teacher-selected content, but be allowed no input into the selection of that content? (p. 170)

Schweisfurth (2015) takes issue with the culturally appropriate nature of the agentic dimension of some frameworks on student-centered instruction. There are some places in the world where high student agency is not culturally appropriate, therefore her framework is intended to make space for that reality:

[The minimum standards set forth here] are not intended to impose a construction of LCE [learner-centered education] which clashes with cultural norms or which demands high levels of teaching resources. Rather, this vision of LCE understands learning as situated within broad cultural norms, within a community and individual context, and based on interactions between teachers and learners. So, for example, the standards do not privilege the individual over the group, or preclude authoritative (as opposed to authoritarian) teacher roles, or rely on technological solutions for successful implementation. (Schweisfurth, 2015, p. 263)

**Bremner: Looking Deeper Yet.** While Starkey examined the literature to determine what previous scholars had prioritized when discussing student-centered learning, she only used ten resources for her analysis. Nicholas Bremner (2021) conducted a meta-analysis of 326 journal articles to create his framework. Utilizing inductive coding of the ten most frequently cited works on student-centered learning from 1996-2017, Bremner determined ten important aspects of student-centered learning. He then applied these ten codes to the 326 journal articles to find out how often each of the codes was mentioned, if there were differences among cultural regions in the world, and if subject matter treated student-centered learning differently.
By looking at places where each of the ten categories were mentioned together throughout the literature, Bremner was able to condense the original ten codes or categories into six primary categories comprising learner-centered instruction: active participation, adapting to student needs, student autonomy, a focus on relevancy and skills, power sharing, and formative assessment. Across the articles, Bremner noted areas of agreement and relative disagreement in incorporating portions of the framework. For example, active participation was mentioned in 80% of the articles, but a humanistic role is mentioned only 13% of the time. In fact, when ranked, the use of formative assessment and incorporating a humanistic focus are mentioned far less than any other component of student-centered instruction. This clearly shows that there is significant disagreement in the field regarding the incorporation of these two constructs as part of student-centered pedagogy.

**Dilemma Theory in the Science Education Literature**

While many educators agree that the Next Generation Science Standards are a strong step in the right direction for K-12 science education as evidenced by their wide adoption (National Science Teaching Association, n.d.), some current research seeks to determine how well enactment of the standards is being executed. Very recently, Cherbow et al. (2020) completed a multiple case study of four schools to determine how the vision of science presented by the NGSS unfolded across several systems of science education. The team shadowed four principals for four months as they supervised science education across their schools. Cherbow et al. (2020) decided to shadow the principals instead of the teachers so they could gather insight into the systems surrounding instruction as opposed to the singular experience of the teacher’s instruction. Analysis of their notes detailed three themes that were consistent across schools: teacher-driven instruction focused on memorization, emphasis on literacy, and hands-on science.
This analysis demonstrates what I see regularly in the field. While principals say they would like to have hands-on instruction happening in science classrooms, an emphasis on literacy and memorization and not student-centered instruction is very common. The systems surrounding the teachers in Cherbow’s study show that there were not unified goals or priorities for science instruction. State data seems to drive priorities in instruction, including a focus on literacy as opposed to the critical thinking and active engagement espoused by the standards and a student-centered approach. Finally, the data suggests that the practice of science instruction in the schools is primarily driven by principal’s vision for what good science instruction is, suggesting that reform efforts should focus on training principals in instructional best practices.

The following section of this chapter will focus on studies about challenges faced when enacting the current recommendations for science instruction. I will demonstrate that, although Windschitl’s dilemma theory was published in 2001, it still holds true. Following that review, I will demonstrate how a recent study shows dilemma theory is at work even more as teachers attempt to teach science through the global Coronavirus pandemic.

**The Conceptual Dilemma**

As was mentioned before, Windschitl says that teachers experience a conceptual dilemma when teachers do not have a deep understanding of constructivist theory or they struggle to reconcile their own epistemology with a constructivist epistemology. In the science education literature, this is clearly demonstrated when teachers have an incomplete science teacher identity. Enacting the science standards and student-centered science instruction requires that teachers view themselves as inquiry-based or student-centered science teachers first and foremost.

Carrier et al. (2017) investigated the intersection of elementary science experiences and teacher preparation on elementary science teacher identity. The novel part of this research comes
from their focus on the teachers’ memories of their experiences in science in elementary school. The goal was to uncover other factors that impact teachers when they are becoming teachers of science in elementary classrooms. The longitudinal case study focused on two teachers for the study. While the researchers acknowledged the limits of small sample size and possible selective memory retrieval, they began their interviews with teachers in their third year of study. The researchers found that positive memories of science instruction helped the two teachers embrace student-centered science instruction during elementary school. Other factors that influenced the identity of these teachers included the teacher preparation program, field experiences, and administrator support at the school during their first year of teaching. In analyzing the information provided, I noticed that during the study, one teacher raised concerns about the varied socio-economic status of students and students’ parental support (p. 1741), which viewpoints are typically associated with racial bias, a cultural dilemma. This finding is ignored in this study but shows that teachers may struggle with more than one pedagogical dilemma and that instructional choices are not made in isolation.

Keiler (2018) completed a descriptive explanatory case study to determine how teachers experience their roles and the shift in their role in student-centered classrooms. She followed thirteen in-practice math and science teachers throughout the PERC program and analyzed teacher interviews and focus groups to gather teacher perspectives. Teachers reported feeling conflict as they experienced the shift from a teacher-centered pedagogy to a student-centered pedagogy. Secondary science teachers frequently view themselves as content experts, and this shift in pedagogy moved their lens from content delivery to content moderation and analysis of student thinking. Many teachers reported enjoying the freedom to know more about what students are doing and thinking as opposed to focusing on content delivery and behavior.
management. A few teachers reported struggling to make the shift and one teacher refused to shift at all, struggling entirely with a conceptual dilemma. This study provides experiences that support the need to support teachers through the shift as they learn to teach with a student-centered teaching identity.

**The Pedagogical Dilemma**

Utilizing students’ pre-conceptions, centering students epistemologically, allowing student sense-making, and facilitating student to student discourse are central components of NGSS and student-centered instruction (Bremner, 2020). Haverly et al. (2020) completed a case study of two student teachers and a first-year teacher that documented their experiences with engaging students in sense-making discussions in the science classroom. By analyzing transcripts of multiple sense-making episodes with students, the researchers discovered that the teachers were willing to make space and share epistemic agency with students. This provided for deep conversations where students engaged in critical thinking about the topic. However, the teachers failed to recognize these conversations as a productive use of time, part of the pedagogical dilemma. The authors suggest that teachers who are new to sense-making need support in how to notice and interpret what students are saying, framing the dilemmas they face as productive struggle and not wasted time, and then to respond in ways that guide student thinking to clearer conclusions.

Professional development is likely one of the most important tools districts can use to support teachers in their move toward enacting the NGSS and student-centered science instruction. Lotter and Miller (2017) used a phenomenological case study of 10 middle school science teachers who participated in the same summer teaching professional development program. The authors recorded and transcribed the focus group conversations as well as written
reflections from the teachers and then used grounded theory to code the transcripts for themes. The authors found that teachers were reflecting mostly at a justification (“I did this because…”) and critique (“X happened when I did this…”) level. The authors also found that teachers were frequently discussing student learning and common misconceptions students held. However, in relation to teaching dilemmas, teachers also frequently commented on challenges students experienced when expected to take on more responsibility through inquiry-based learning. The teacher reflections shed light on how student struggles impact teacher willingness to engage in student-centered instruction. The authors found teacher reflection and processing to be an important step in successful navigation of this dilemma.

**The Cultural Dilemma**

Windschitl frames the cultural dilemma within both classroom culture and behavioral expectations as well as cultural frames of reference. I will show that it is the cultural frame of reference, which dictates teachers’ beliefs about students, that contributes to decreased quality science education and achievement for students of color.

Kang and Zinger (2019) studied how to prepare novice science teachers for equitable instruction. The authors used a case study approach to follow three white secondary science teachers who taught primarily Latinx students for three years. They gathered vision statements, artifacts, teaching episodes (observations), and interviews to interpret ways the goals of science instruction were framed for students. Further, the authors observed how teachers positioned students’ lived experiences throughout their teaching. First, the authors found that each of the teachers had a markedly different trajectory for moving through the process of becoming a more student-centered science teacher, even though they shared similar experiences throughout the process. Second, the researchers found that the novice teachers’ “underdeveloped critical
consciousness” (Kang & Zinger, 2019, p. 841) prevented them from creating inclusive lessons for their students. The authors found that framing instructional practices with the Ambitious Science Teaching framework allowed the novice teachers to develop more critical consciousness and begin to center the experiences of their students more effectively.

Critical consciousness and teacher bias are also important indicators of teachers’ willingness or ability to provide robust inquiry-based science education for students. Chen and Mensah (2018) utilized a collective case study of three preservice teachers’ social justice science teacher identities as they moved through a science methods course and student teaching experience while in University. The authors utilized teaching journals, final papers, interviews, and observations to gather anecdotes about teacher identity and shifts. The authors found that cooperating teachers have a strong influence in building the identity of the preservice teacher as a reform-minded science teacher. The more centrally the student teacher was positioned in classroom instruction, the stronger their science teacher identity became. Further, the positioning of the student teacher in the classroom impacted their ideology regarding student capabilities. Preservice teachers who are positioned as observers tend to hold on to deficit ideologies about marginalized populations of students and their science capabilities, whereas preservice teachers who were positioned centrally in the classroom were able to move past deficit ideology into constructive instruction with students.

Similarly, Mark et al. (2020) studied pre-service teacher’s positionality and cultural competence during the student teaching experience. While the study title does not invoke the language of science teacher identity development, the study is similar to that done by Chen and Mensah (2018) in that it is considering how the students’ cultural competency and their social justice identity develop over time, even if that identity is not apparent to the student due to their
whiteness. The authors also looked at how power structures might impact the agency of the teachers during their clinical experiences. Mark et al. (2020) conducted interviews with each of five participants in the study near the end of their clinical experience. Specific questions in the interviews were aimed at the nature of the clinical experience activities, factors that were helpful or not to their learning, and reactions to statements regarding dominant beliefs of teachers about students when working in urban settings.

A major finding of the paper was that pre-service teachers who identified as having embedded (holding responsibility for teaching regularly) or peripheral (somewhat involved in teaching, but not the main instructor) positionalities regarding their overall activity within the clinical classroom were critical of dominant deficit beliefs about students, which is similar to the findings of Chen and Mensah. One student in the study who had a conflicted (took issue with the school system and the teaching methodology) positionality regarding his overall activity within the clinical classroom also espoused a conflicting positionality regarding the deficit beliefs of students. Some of his beliefs were critical of harmful dominant beliefs and some of his beliefs were problematic, blaming students for their poor performance in school.

Similarly, Mangiante (2018) observed two elementary science teachers teaching in poor, diverse communities and documented their instructional decisions as they worked through a curriculum. One common deficit belief of science teachers was reinforced during this study: teachers often believe that students from poor communities have no background knowledge. In this study, it led teachers to allow students less time for exploration, discovery and sense-making, and to instead adopt a more teacher-centered approach to science instruction. However, with support, the teachers in Mangiante’s study were able to plan more student-centered instruction, underscoring the need for professional development and support.
Two authors have done work to shed light on best practices for moving past deficit ideology to empowering students through understanding and teaching with their sociopolitical reality at the fore. Madkins and McKinney de Royston (2019) conducted a case study of one teacher who consistently embodied all three tenets of Culturally Relevant Pedagogy (CRP). The case study was used to illuminate what CRP looks like in action and how it impacts students. The teacher demonstrates political clarity by facing deficit ideologies about students head-on. He names them in the class with students and then builds a system of high expectations and love coupled with strong instruction to encourage students to be their strongest scientific selves. As a result, students engage happily and deeply in the content he has prepared for them.

The teacher in Madkins and McKinney de Royston’s (2019) study was a young Black man. Sheth (2019) conducted a similar study but with white teachers. Sheth found that, while the white teachers were attempting to use culturally relevant pedagogy by connecting to students’ experiences, creating interest in science, representing scientists as role models, and scaffolding instruction. However, because of the teachers’ whiteness, they often maintained unequal power dynamics in the classroom by centering their own understanding of science and ignoring or negating the historical or current realities of the students of color they were teaching. As a result, science was still painted as a non-political and non-racial subject, when that is not true. The authors posit that teachers need to be willing to confront the historical and lived realities of their students and position their students’ identities at the center of instruction in more than a token manner.

**The Political Dilemma**

The final dilemma proposed by Windschitl includes any force outside of the immediate classroom that dictates how a teacher can teach or what a teacher can teach about. Wei et al.
(2019) used a case study to analyze the shift in science teaching identity of a first-year physics teacher as he tried to enact his beliefs about hands-on science instruction. The authors gathered observations and interviews throughout the teacher’s first school year and used grounded theory to code for recurring themes in the teacher’s experiences. The data shows that the teacher loved inquiry science when he was in school and hoped to promote that type of instruction in his own classroom. However, the system surrounding the teacher did not support effective inquiry instruction and therefore stunted the inquiry-based identity development of the teacher.

“Contextual factors, such as [testing] accountability, textbooks’ constraints, and tight time schedules” (p.17) prohibited the teacher from enacting a more student-centered focus in his classroom (Wei et al., 2019).

Mark et al. (2020) note in the literature review portion of their study, which focused on cultural dilemmas, that teachers who developed critical positionalities regarding bias beliefs and social injustice were unable to maintain those positionalities and enact student-centered instruction due to school contexts and high stakes accountability measures. This is particularly true of one student in their study. In the findings, it is difficult to tease out if the student with a conflicted positionality regarding students is a result of the students or because of adult management of the clinical experience. Here, factors outside of the teachers’ classroom provided the dilemma. There were many places in the interview where this student stated issues of test-preparation focus, lack of support from his cooperating teacher, lack of support from the university, and lack of support from the administrative team at the school in completing his pre-service clinical. In light of Windschitl’s dilemma theory, it is interesting to wonder as well whether there is a causal relationship between adult management issues (political dilemmas) and
problematic beliefs about students. In other words, do disgruntled teachers hold more negative beliefs about students because of their own negative interactions with adults?

**The Most Recent Added Challenge: Teaching During a Global Health Crisis**

The current study sought to understand the dilemmas student-centered science teachers faced when trying to enact instruction during the global pandemic. Other studies have shown impacts on science instruction during the pandemic. Iveland et al. (2021) presented preliminary findings on the impacts of COVID-19 on enactment of the NGSS at the National Association of Research in Science Teaching Conference in April of 2021. The researchers used a survey to ask teachers what their teaching practices were like during the pandemic as well as what opportunities and challenges teachers were experiencing when trying to teach. Among many things, teachers reported that students were spending far less time on science than before the pandemic and that student discourse is happening less than before. Further, teachers’ top-three reported instructional methods were watching videos, reading material online or in print, and online class meetings. These findings indicate political dilemmas (time dedicated to science), but don’t parse out why student discourse is limited or why their teaching practices shifted so significantly. Further, the study was limited to almost entirely middle school teachers in California. The present study builds on this research.

**Summary**

Most of the science education community in the United States agrees that teaching by centering students epistemologically is the most effective way to provide meaningful, accessible, and equitable instruction to students in K-12 classrooms. Unfortunately, studies have shown that teachers face many dilemmas when attempting to execute science instruction “with” students. Mark Windschitl (2001) names the challenges teachers experience as conceptual, pedagogical,
cultural, and political dilemmas. This study used Windchitl’s theoretical framework to explore the challenges teachers faced while attempting to maintain student-centered instruction during the COVID-19 pandemic. In the next chapter, I will detail the methods used in this study to look more closely at teachers’ perceptions of their practice and the dilemmas they faced throughout the pandemic.
Chapter 3 – Methods

The science community has been working towards three-dimensional student-centered instruction for quite some time. However, research shows that execution of this vision is not consistent among educators K-12 with teachers being impacted by many dilemmas as they plan and execute their instruction (Bang et al., 2012; Bianchini & Cavazos, 2007; Caspari-Gnann & Sevian, 2022; Hammerness, 2004). The arrival of the COVID-19 pandemic in the late winter and spring of 2020 further complicated science education practice. This study looked at the impact of the pandemic on the student-centered nature of science instruction and the specific dilemmas teachers faced while trying to maintain rigorous, student-centered instruction.

Research Design, Setting, and Participants

This study was an explanatory sequential mixed methods study that utilized a larger quantitative survey response coupled with a smaller set of interviews for qualitative data. “The explanatory sequential design is a mixed methods design in which the researcher begins by conducting a quantitative phase and follows up on specific results with a subsequent qualitative phase to help explain the quantitative results” (Cresswell & Plano-Clark, 2018, p. 77). The interviews were conducted with a subset of the survey respondents to gather more context about their experiences and the dilemmas they faced while teaching science through the pandemic.

Setting

Volunteer members of the National Science Teaching Association (NSTA) were sampled for this study via in-person survey. NSTA is the largest science teachers’ organization in the United States and has a membership of about 40,000 science practitioners spanning all grade levels (National Science Teaching Association, 2021). NSTA was chosen as the vehicle for this
study as the NSTA teacher population could provide the most diverse experiences from a national lens.

**Site Entry and Informed Consent**

Permission for conducting the study was sought from the President of the NSTA. “Getting permission to ask people to open up to a researcher or to enter a setting to collect data often requires approaching the organization’s gatekeepers, either in a letter, via email, or over the phone” (Marshall & Rossman, 2016, p. 107). For this study, the president was reached through a mutual contact and via email. The email specified the purpose of the research and its potential benefit to the greater body of knowledge, who would be presented with the opportunity to participate and why, when they would be reached, and specifics on the timeline of the study. The email assured the president that teachers could exit the study at any point and that their individual consent was requested before participation begins. A preliminary conversation with the site contact and the president of the organization had already demonstrated initial willingness to participate. To further ensure consent, all interviewees were required to complete an Informed Consent Form (see Appendix A) prior to participating in the study.

**Participants**

Following written consent from the president of the NSTA, participants were originally going to be recruited by posting in the elementary, middle school, and high-school listservs. Teachers that volunteered from each grade-band (grades K-2, 3-5, 6-8, 9-12) would have been selected to participate in the study. Unfortunately, very few participants returned the survey virtually after three weeks had passed. Creswell and Guetterman (2019) note that return rates for online surveys and questionnaires are notoriously low. Further, Saleh and Bista (2017) found that return rates on surveys delivered through email were even lower than other methods. Therefore,
it is not surprising that teachers did not respond to something digital in any meaningful way. Therefore, I sought permission to attend the NSTA regional conferences and ask respondents in person to complete the survey. After this permission was granted by the President of the organization, I attended each conference (Portland, OR October 2021; National Harbor, MD November 2021; Los Angeles, CA December 2021). In-person data collection provided a much higher response rate.

Once teachers were recruited at the NSTA conferences, they were asked to complete a paper version of the survey (located in Appendix B). Some respondents were offered the opportunity to complete the survey digitally (as they expressed being pressed for time at the moment of contact), but no respondents completed the survey in this manner. In total, 133 survey respondents were generated across all three conference sessions. Table 3.1 below shows the construct of the survey respondents by grade-band.

**Table 3.1**

*Quantitative Survey Respondents by Grade Level*

<table>
<thead>
<tr>
<th>Grade Band</th>
<th>K-2</th>
<th>3-5</th>
<th>6-8</th>
<th>9-12</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Respondents</td>
<td>12</td>
<td>13</td>
<td>51</td>
<td>57</td>
<td>133</td>
</tr>
</tbody>
</table>

To gather participants to interview, the final question on the survey asked participants to supply their email address if they were interested in participating in a short interview to follow up about their responses. Qualitative interviews for this study were conducted with a subset of the same participants from the larger quantitative portion of the study. Creswell and Plano-Clark (2018) explain:

Since the explanatory sequential design aims to explain initial quantitative results, we recommend that the individuals for the qualitative follow-up phase be a subset of individuals who participated in the quantitative data collection. The intent of this design
is to use qualitative data to provide more detail about the quantitative results, and the individuals best suited to do so are ones who contributed to the quantitative data set. (p. 190)

Stratified random sampling was used to identify teachers to interview for the qualitative portion of this study. “In stratified sampling, researchers divide (stratify) the population on some specific characteristic and then, using simple random sampling, sample from each subgroup (stratum) of the population” (Creswell & Guetterman, 2019). For this study, teachers who indicated a willingness to be interviewed were stratified into categories based on grade-level taught (K-2, 3-5, 6-8, 9-12). Two teachers from each grade-band were then randomly selected and contacted for interview. More qualitative samples were initially planned, but the quantitative results showed no distinct difference between the teaching styles of teachers in each grade-band and saturation in narrative was reached at two interviewees per grade-band. Marshall and Rossman (2016) note:

The researcher notices when he sees or hears the same patterns repetitively, and senses that little more can be gained from further data collection since there is saturation of the data…Triangulation needs to be built into the setup of data collection early on. Still, it is projected as a strategy that will help the researcher assert that his data interpretations are credible. (p. 229)

For this study, qualitative interviews were coupled with the drawings and descriptions teachers created in their surveys in order to triangulate qualitative data and justify sample size.

After they were randomly selected, teachers were emailed with a personalized email to set up an interview via zoom. Teachers were contacted again after three days if they didn’t respond a first time. If the teacher did not respond, a second teacher was contacted, and so forth
until either all participants in that grade-band were contacted and declined, failed to respond, or agreed to participate.

**Quantitative Instrumentation**

The Draw-A-Science-Teacher-Test-Checklist (DASTT-C) comprises the core of the survey instrument (Thomas et al., 2001). The DASTT-C was used to gather data about the student-centered nature of instruction during the pandemic for quantitative and qualitative analysis. In this instrument, participants were asked to draw three pictures of their science classroom, including the teacher and the students, one for each of the ’19-’20, ’20-’21, and fall of the 2021 school years. Teachers were also asked to write a brief explanation for each drawing describing what the teacher is doing and what the students are doing in the drawing. The beginning of the survey also included a few additional questions to capture the grade-level taught, school name, school district, and state in which the teacher works to gather the socio-economic and ethnicity data for quantitative analysis. See Appendix B for the full survey.

The choice to use a survey tool that identifies the student-centered nature of science classrooms as opposed to gathering data regarding teachers’ use of specific NGSS practices in the classroom was intentional. First, student-centered instruction is an underlying assumption of the *Framework for K-12 Science Education*, which is the foundation for the Next Generation Science Standards:

The framework…is designed to help children continually build on and revise their knowledge and abilities, starting from their curiosity about what they see around them and their initial conceptions about how the world works. The goal is to guide their knowledge toward a more scientifically based and coherent view of the sciences and engineering, as well as of the ways in which they are pursued and their goals can be
the framework emphasizes that learning about science and engineering involves integration of the knowledge of scientific explanations (i.e., content knowledge) and the practices needed to engage in scientific inquiry and design. Thus the framework seeks to illustrate how knowledge and practice must be intertwined in designing learning experiences in K-12 science education. (National Research Council, 2012, p. 11)

Built on the Framework, The Next Generation Science Standards enumerate more specific practices regarding the content of the instruction (including Crosscutting Concepts, for example), and assume that teachers are centering the classroom around student investigation, student talk, and student ideas. Therefore, a student-centered approach must occur for NGSS to occur.

Second, there are many states that have not adopted the Next Generation Science Standards or have only adopted parts of the standards (NGSS, 2013). However, the standards that are adopted in most places still require a student-centered approach in the classroom because they’re based on the NGSS. Further, teachers working in a state that does not utilize NGSS standards may not be familiar with the language in the standards or normed on specific words that an NGSS-based tool would use, complicating any conclusions drawn in a study.

The Draw-A-Science-Teacher-Test is a tool that is frequently used to observe teacher beliefs about their practices (Akkus, 2013; Al-Amoush et al., 2011; Markic et al., 2006; Markic & Eilks, 2012). It is often used with pre-service teachers to gauge how they view the practice of science teaching and pre-dates the genesis of the NGSS. There are, however, studies that have also utilized the DASTT-C to capture teacher practice (Markic & Eilks, 2006), providing precedent for how the tool was used in this study.
**DASTT-C Aligns with the Conceptual Framework**

The Draw-A-Science-Teacher-Test is a suitable tool for the conceptual framework being utilized to ground this study. First, the DASTT-C is well-aligned to Neumann’s definition of teaching that is “with” students (Neumann, 2013). The developers of the tool were careful to design something that captured learning that occurs “with” students rather than “on” students. Neumann (2013) describes learning that focuses “on” students as learning that happens to students, similar to the description above:

> These contexts allow students choices within curricular frameworks established by or through the teacher. Land and Hannafin’s (2000) position, stated above, seems to reflect this relationship: students work towards “external learning goals” established by the teacher. These contexts require well-conceived blueprints and guide students through objectives, content, and questions posed by the teacher, usually with little to no input from students. (p. 166)

Thomas et al. (2001) explain:

> DASTT-C development began with a listing of teacher-centered and student-centered attributes of an elementary science teacher rather than a scientist. This listing determined *teacher-centered* as those classrooms and teaching events where the teacher is at the center of instruction and learning. In this instructional model, the teacher is the knowledge conduit. Student input is acknowledged but not expected and the learning curriculum is focused on specific outcomes. (p. 298)

Clearly, the tool and the framework are aligned on the definition of teacher centered.

Neumann (2013) describes student-centered learning as learning that occurs “with” students. “Student-centered contexts that center *with* students emphasize partnership between teachers and students. Because students are seen as free beings, teachers enlist students in a more
reciprocal learning relationship” (p. 167). In comparison, in order to create a student-centered tool, Thomas et al. (2001) go on to say:

In a student-centered classroom, the students are at the center of learning and the teacher guides or facilitates activities and investigations. The classroom environment is open and encourages student inquiry and exploration. Students manage their own learning and generally set the direction in which lessons proceed. (p. 298)

Given these descriptions, the DASTT-C is aligned with Neumann’s framework for student-centered learning, identifying learning that is less “on” students and more “with” students.

The DASTT-C is also aligned with Windschitl’s (2001) dilemma theory. In describing his own theoretical conception of constructivist teaching, which grounds his entire dilemma theory, Windschitl references Dewey’s conceptualization of constructivism (Windschitl, 2001, p. 134). Neumann’s framework (2013), with which the DASTT-C (Thomas et al., 2001) aligns, also utilizes Dewey’s conceptualization of constructivism as the rationale for learning that centers “with” students (p. 167). Therefore, Windschitl and Neumann are using nearly the same definition of constructivism in their work.

The first dilemma discussed in Windschitl’s (2001) theory is the conceptual dilemma. He defines the conceptual dilemma as, “grasping the underpinnings of cognitive and social constructivism; reconciling current beliefs about pedagogy with the epistemological orientations necessary to support a constructivist learning environment” (p. 133). Because Windschitl positions the conceptual dilemma with teachers’ beliefs, the DASTT-C, originally created to gather information about teachers’ beliefs, will demonstrate whether a teacher is struggling with a conceptual dilemma. The other dilemmas Windschitl describes (Pedagogical, Cultural, and
Political), fall outside of these beliefs and were examined through the qualitative portion of the study.

**Coding the DASTT-C**

Teacher drawings from the survey were coded using an adjusted coding guide like that proposed by Thomas et al. (2001). Thomas et al. specified a 13-point score sheet for coding teacher drawings. The scores are broken into groups of points for the teacher, the students, and the environment. If the behavior on the score sheet is occurring in the drawing, the drawing earns one point. If not, the drawing earns zero points. There are a total possible 13 points. With the switch to completely virtual instruction in many places, several statements on the DASTT-Checklist were modified to accommodate virtual scenarios. The full checklist is in Appendix C. In accordance with Thomas et al. (2001), coding was conducted for each drawing by incorporating the data from the drawing as well as the short description that was supplied on the survey by the teacher.

**Validity**

Creswell and Plano-Clark (2018) “define validity in mixed methods research as employing strategies that address potential threats to drawing correct inferences and accurate assessments from the integrated data” (p. 251). Here I will address the validity of the DASTT-C and other threats to validity that arose during the study.

**Validating the DASTT-C**

Thomas et al. (2001) attended to validity of the DASTT-C instrument during development. First, the team developed a pilot checklist of items on the DASTT-C from the literature. Then, five raters scored 10 samples independently using the pilot checklist. A phi coefficient was then calculated to determine the relationship of scores among raters for each
item. Any item receiving a 0.70 or higher was kept verbatim and an item receiving a score below 0.70 was eliminated or modified.

Following the initial item development, five raters then re-scored a complete set of pictures using the updated DASTT checklist. An analysis of variance (ANOVA) was completed on the five scores for each item and no significant difference was found among the scores or total scores of the DASTT-C. Finally, a coefficient alpha was calculated to determine reliability of the checklist. Creswell and Guetterman (2019) indicate several ways to examine the consistency of rating:

The consistency of responses can be examined in several ways. One way is to split the test in half and relate or correlate items. This test is called the Kuder-Richardson split half test (KR-20), and it is used when (a) the items on an instrument are scored right or wrong as categorical scores, (b) the responses are not influenced by speed, and (c) the items measure a common factor. (p. 161)

Thomas et al. (2001) calculated a Kuder-Richardson 20 and the “coefficient alpha was 0.82 indicating a high degree of internal consistency in the instrument” (p. 303). For this study, there is a threat to validity with the instrument. As discussed earlier, the checklist was modified slightly for this study to incorporate evidence of student-centered instruction in a virtual environment. Four items on the checklist were modified to include virtual environment characteristics (document camera, Google classroom, simulations, and breakout rooms).

Further, as the sole researcher for this study, it was important to pay careful attention to reliability of data coding while scoring teachers’ drawings. “Quantitative reliability means that scores received from participants are consistent and stable over time” (Creswell & Plano-Clark, 2018, p. 217). To ensure reliability across samples, I maintained memos on the DASTT checklist.
to indicate scores I had given to very specific instances encountered in the drawings. Further, as I scored the drawings, I looked back and forth between many drawings to norm myself across all the drawings. Finally, I kept individual tallies on every drawing and the tallies were kept in exact order of the checklist. If a trait from the checklist was present, a 1 was indicated as a tally. If a trait from the checklist was not present, a zero was marked instead. In this way, it was easy to compare the drawings to each other for consistency. Scores among the drawings were assigned and then compared for the first 40 surveys, for a total of 120 comparison points. At that time, it was decided that consistency had been reached and the rest of the surveys were scored independently.

**Further Quantitative Data Collection**

Once teachers submitted their surveys, data were collected from the National Center for Education Statistics and entered into SPSS to match the information provided at the beginning of the survey by each teacher. First, school name and state were entered into the national database. Once the school was located, the percent of the student body that is eligible for free and reduced lunch was entered into SPSS. Further, the percent of the student body that is non-white will also be entered into the data. This allowed for quantitative correlation along a continuous scale between percent free and reduced lunch, percent non-white, and how student-centered instruction is.

**Quantitative Data Analysis**

The quantitative portion of the study was derived by analyzing the scores of the DASTT-C in different contexts to determine shifts and patterns in the student-centered nature of instruction, as perceived by teachers. In an explanatory sequential mixed methods study, “the
researcher designs a quantitative phase that includes collecting and analyzing quantitative data” (Creswell and Plano-Clark, 2018, p. 78).

**Comparing Across Years**

A repeated measures ANOVA with a pairwise comparison and descriptive statistics was used for quantitative analysis to check for differences in the mean scores on the DASTT-C between the groups of teachers across all three timeframes. Teachers’ mean score on the DASTT-C was compared from their perceived instruction in 2019 to their instruction in fall of 2020 and to their instruction in the fall of 2021. A repeated measures ANOVA was chosen because the same group of teachers were being compared at each timeframe, were independent of each other, and the scores on the DASTT-C were found to be normally distributed, therefore not violating any assumptions of the test. Pallant (2020) states, “What you need [for a repeated measures ANOVA]: One group of participants measured on the same scale on three different occasions” (p. 274).

To use a one-way ANOVA, the samples across the timeframes would have to have been independent of each other to avoid violating assumptions of the test, thereby justifying a repeated measures ANOVA test. Caution must be exercised in reporting the results of the repeated measures ANOVA, however. Teachers in the study were not actually assessed at different times but rather were assessed based on their perceptions, or memories, of those different times. Therefore, the results are reported as being their perceived instruction and not their actual instruction.

**Comparing Instruction by Grade-Band**

A one-way ANOVA was used to determine differences in mean DASTT-C score between participants in different grade-bands (K-2, 3-5, 6-8, 9-12). The scores on the DASTT-C by
grade-band meet the assumptions of the test: the scores are on a continuous scale, are normally
distributed, and samples are independent of each other (Pallant, 2020). Samples are independent
because the teachers were randomly selected and not from the same schools. Therefore, there is
very little chance that the score one teacher in the K-2 grade-band affects the score from a
teacher in the 3-5 grade-band.

**Looking for Relationships in School Demographics**

To determine the relationship between socio-economic status of the student population or
the percent of minority students in the population and teacher perceived practice, a Pearson
correlation was conducted. As Creswell and Guetterman (2019) write, when the independent
variable is continuous and the dependent variable is also continuous, a Pearson correlation can be
conducted.

**Qualitative Data Collection and Analysis**

The qualitative portion of this study was used to provide context for the quantitative
results. “Qualitative research is pragmatic, interpretive, and grounded in the lived experiences of
people” (Marshall and Rossman, 2016, p.2). This study followed a multiple case study approach
to gather the context of several teachers’ lived experiences during the COVID-19 pandemic.
Following data collection, the broader quantitative data were mixed with the qualitative data to
look for similarities and differences in reported experiences and tell the story of science teachers’
dilemmas through the pandemic.

**Qualitative Data Collection**

Semi-structured interviews were conducted using the Interview Guide found in Appendix
D. Interviews were conducted using the Zoom digital platform instead of via phone so the
researcher could see body language and responses for ease of establishing rapport with the
interviewee quickly as well as for reflection purposes (Marshall & Rossman, 2016). Interviews were stored on a password secured computer to maintain security of the data. The interviews will be destroyed three years after the study is completed. While the interview guide provided structure for the interview, semi-structured interviewing allowed space for the researcher to ask follow-up questions when the interviewee stated something that was of interest. “We argue that the richness of an interview is heavily dependent on these follow-up questions” (Marshall & Rossman, 2016, p. 150).

Entrance and exit from the interview, building rapport, and confidentiality were all important considerations during the semi-structured interviews. Interviews took no more than 60 minutes. At the start of the interview, participants were reminded that they could stop participation in the interview at any time. To build rapport as well as to provide some reciprocity for the participants, the researcher was sure to thank participants for their time and remind them how important and useful their interview was to the study. “One of the most important aspects of the interviewer’s approach is conveying the attitude that the participant’s views are valuable and useful” (Marshall & Rossman, 2016, p. 148). To further build rapport, the researcher shared some information about their professional and doctoral journey but was brief in order to center the narrative of the participant and not the interviewer.

While there was an interview guide that provided some structure to the interview, it was important that the researcher remained focused on probing with follow-up questions that allow the participant to elaborate on their experiences. This allowed the researcher to gather the full context to support analysis as well as to show the participant that the researcher was listening carefully and was interested in what the participant was sharing. Marshall and Rossman (2016) indicate that follow-up questions could come in three forms: “(1) open-ended elaborations, (2)
open-ended clarifications, and (3) detailed elaborations” (p. 150). Field notes were kept for the duration of every interview, allowing for cycles of reflexivity throughout the process. The field notes were an important part of maintaining fidelity to the participants’ stories and for bracketing out personal experiences, as noted in the positionality section of this proposal. While “it is difficult to fully bracket one’s experiences as a qualitative researcher” (Marshall & Rossman, 2016, p. 118), it is nevertheless imperative.

**Qualitative Data Analysis**

All interviews were transcribed verbatim and imported into the Dedoose software (2018). To maintain ethical transparency and fidelity to the participant’s experience, all language was left in the interview transcription as-is (Marshall & Rossman, 2016, p. 212). For this study, the dilemmas outlined in Windschitl’s dilemma theory of science education were be used for deductive coding. “Deductive coding is when you already have a predetermined scale or set of tags that you want to use on your data” (Frampton, 2020, para. 5). Memos were kept as the data were coded. These memos were used to check researcher reflexivity and to maintain fidelity to the participants’ expressions (Marshall & Rossman, 2016). Further, these memos were used to begin to construct the narrative experience of teachers. Teacher quotes within each code were then organized into themes and connected with the quantitative data for complete analysis and narrative construction.

**Trustworthiness**

Marshall and Rossman (2016) identify many areas that must be considered to establish trustworthiness in a qualitative study (p. 46-47): triangulation, disconfirming evidence, engaging in reflexivity, member checking, prolonged engagement in the field, collaboration with participants, developing an audit trail, and peer debriefing. Marshall and Rossman write that in-
depth interviews are “often supplemented with other data” (p. 102). While the qualitative portion of the study was conducted using only one interview session per individual, the data was compared to the quantitative data, drawings, and descriptions gathered for the mixed-methods study to offer more depth and opportunities for triangulation. This quantitative data was also used to look for conflicting or disconfirming evidence.

**Positionality and Bias**

My positionality as a professional developer coupled with my experience teaching through the pandemic were important factors to consider throughout this study. In my time as a novice teacher, I was coached by a more experienced teacher and I learned that direct instruction was not getting my students where they needed to be. I quickly began working on methods of instructing students where they constructed meaning from experiences they had and then used that meaning to explain other phenomena. While the DASTT-C is a tool specifically designed for student-centered instruction, Ozola (2012) states:

> Constructivism is a view of learning that knowledge is not a thing that can be simply given by a teacher at the front of the classroom to students at their desks. Rather, knowledge is constructed by learners through an active, mental process of development and learners are the builders and creators of meaning and knowledge. The constructivist conception uses student-centered teaching strategies because this type of learning will help students develop critical thinking and collaboration skills and learning takes place in environments where students are able to participate actively. (p. 426)

Stumbling on this constructivist approach for me changed the trajectory of my students. They were excelling and excited about science in my classroom for the first time. I became known as a leader in science instruction in our organization and rose into leadership with the
goal of training the 26-school network how to “do” inquiry science. It was during this transition that I learned that there was a whole movement nationwide and a set of standards we could use that promotes teaching students with inquiry science.

Later, in my work consulting across the country, I frequently encountered school systems that fail to set science teachers and students up for success. School systems are beholden to federal expectations as well as local financial and political realities that temper their focus on robust science education. Many times, administrator knowledge gaps constrain teachers when the teachers are epistemologically equipped themselves to execute constructivist pedagogy. Finally, I had the honor of teaching science to approximately 400 students remotely during the 2020-2021 school year due to the COVID-19 pandemic. I experienced many dilemmas while trying to enact student-centered and constructivist instruction with these students. These experiences have led to my interest in this study and were a lens through which I needed to be reflexive in this study.

My experiences will allowed me to ask more pointed questions during the interview but could also cause me to look for patterns in my qualitative data that are not strongly supported, imposing my own biases, views, and experiences onto the study. It is also important for me to acknowledge that I have an outsider perspective when approaching this study. It was critical for me to listen carefully to the participants and really hear their experiences and honor their voices. While I do not have any ethical considerations regarding being in a position of power and authority or performing a covert study, there are ethical considerations about preserving participant voice.

Summary

This exploratory sequential mixed-methods study sought to analyze how and why teachers’ perceived science instruction shifted throughout the COVID-19 pandemic. The
quantitative portion of the study was conducted using a modified Draw-A-Science-Teacher-Test-Checklist to indicate how student-centered teachers’ perceived instruction was during the fall of 2019, fall of 2020, and the fall of 2021. Scores were coded and analyzed using ANOVA tests and Pearson’s correlations. A small set of qualitative interviews was also conducted and coded using Windschitl’s dilemma theory to generate codes and organize the data. The quantitative scores and the qualitative quotes and codes were mixed to tell the story of teachers’ experiences throughout the pandemic. In the next chapter of this dissertation, I will review the quantitative results of the study.
Chapter 4 – Results

In this chapter, I discuss the quantitative results of the study. For this study, volunteer teachers that attended the 2021 regional National Science Teaching Association conferences completed the Draw-A-Science-Teacher Test (DASTT) survey. I analyzed those surveys using a modified checklist (DASTT-C) to determine the degree of student-centeredness of teachers’ classrooms. The question being answered in this chapter is: In what ways did the student-centered nature of teachers’ perceived instruction change while the science education community was experiencing a pandemic? In summary, the results show that teachers’ perceptions of their classrooms became more teacher-centered after the onset of the pandemic. Further, the results show that teachers’ perceptions of their classrooms are moving back towards student-centered this year but have not returned fully to pre-pandemic instruction.

Total scores on the DASTT-C can range from zero to thirteen. A lower score indicates a classroom that is more student-centered. Scores in the 0-4 range are considered “exploratory” in nature. In exploratory classrooms, teachers believe students can manage their own learning and the teacher leads or guides the student investigations. Conversely, a higher score indicates a classroom that is more teacher centered. Scores in the 5-9 range indicate classrooms that are “conceptual” in nature. In conceptual classrooms, teachers believe students need “themed” learning experiences and the teacher “organizes the content and processes of science.” Finally, scores in the 9-13 range are considered “explicit” in nature. In explicit classrooms, the teacher believes students “need assistance in learning” and the teacher is the “knowledge conduit” for students (Thomas et al., 2001, p. 310).

This chapter will discuss the results of the study, First, the mean DASTT-C scores are statistically significant year-to-year. These results will be coupled with samples of teacher responses on the DASTT that exemplify those shifts. Further, an example of a more teacher-
centered classroom that is being conducted virtually will be shown. Because 71% of all survey respondents indicated a switch to remote instruction during the 2020 school year, it is important to highlight what scores in those settings look like as the original DASTT-C was created for in-person instruction. Following an analysis of teacher perceptions of their classrooms from year to year, the DASTT-C scores for classrooms in each grade-band are discussed and show that they did not differ significantly. Finally, the data shows that there is no relationship between the socio-economic status or demographic make-up of the student body and the score on the DASTT-C in this study.

**Instruction Throughout the Pandemic**

A Repeated Measures Analysis of Variance (ANOVA) was used to determine differences in the mean score from the Draw-A-Science-Teacher-Test, which measures how student-centered teachers’ classrooms are perceived to be by the teacher. A Repeated Measures ANOVA is appropriate when comparing the mean scores for the same subject on three or more occasions (Pallant, 2020). In this case, the comparison is between teachers’ perceived instruction classroom instruction in 2019, 2020, and 2021. A One-Way ANOVA was another possibility for this test because it compares mean scores between groups. However, the scores for a teacher in 2019, 2020, and 2021 are not independent of each other because it is possible the score on the 2019 drawing influences the 2020 and 2021 drawings. As such, it was more appropriate to use a Repeated Measures ANOVA.

Table 4.1 contains the pairwise comparison data for the Repeated Measures ANOVA for different years and shows that there is a significant difference in the scores on the DASTT-C as reported at the three different timeframes. Time one is 2019, time two is 2020, and time three is 2021. The score in 2019 (4.47) is significantly different than the score in 2020 (7.36) with a
significance level of $p < 0.001$. The score in 2019 is statistically different in 2019 (4.47) when compared with 2021 (5.59) as well, with a significance level of $p < 0.005$. Finally, the score in 2020 (7.36) is also statistically different than that of 2021 (5.59) with a significance level of $p < 0.001$. Therefore, the perceived student-centered nature of the science classroom was different at each timeframe.

**Table 4.1**

*Repeated Measures ANOVA Comparing DASTT Score Across Time*

<table>
<thead>
<tr>
<th>(I) Time</th>
<th>(J) Time</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>2020</td>
<td>-2.897</td>
<td>.295</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>2021</td>
<td>-.888</td>
<td>.277</td>
<td>.005</td>
</tr>
<tr>
<td>2020</td>
<td>2019</td>
<td>2.897</td>
<td>.295</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>2021</td>
<td>2.009</td>
<td>.275</td>
<td>.000</td>
</tr>
<tr>
<td>2021</td>
<td>2019</td>
<td>.888</td>
<td>.277</td>
<td>.005</td>
</tr>
<tr>
<td></td>
<td>2020</td>
<td>-2.009</td>
<td>.275</td>
<td>.000</td>
</tr>
</tbody>
</table>

Further, a partial eta-squared of 0.492 demonstrates a large effect size, allowing the results to be generalizable outside of this study. Geert van den Berg (2021) shows a partial eta squared of 0.14 or greater indicates a large effect size and is corroborated by Pallant (2021).

As seen in Table 4.2, teachers reported an average score of 4.47 on the DASTT-C in 2019 before the pandemic. This indicates that classrooms were perceived as very student-centered and exploratory. During the first year of the pandemic, teachers reported an average score of 7.36 on the DASTT-C. This indicates that perceived instruction shifted towards teacher-centered during that time, but instruction was not quite “explicit.” Interestingly, teachers reported an average score of 5.59 in 2021. This indicates that perceived instruction has shifted back towards exploratory but has not returned to pre-pandemic levels (4.47). Again, each of these year-to-year differences was significant ($p < 0.01$).
Table 4.2

Comparing Means Across the Years

<table>
<thead>
<tr>
<th>Year</th>
<th>N</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>107</td>
<td>4.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>107</td>
<td></td>
<td>7.35</td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td>107</td>
<td></td>
<td></td>
<td>5.34</td>
</tr>
</tbody>
</table>

One of the nice things about the DASTT-C as a tool is that it asks teachers to supply a picture as well as a description detailing what students and teachers are doing. Below are some excerpts from surveys that corroborate the statistical findings from above. Images 4.1 and 4.2 show an example of a drawing and description made by a teacher that began instruction with a more student-centered approach in 2019 and had to move to a more teacher-centered approach in 2021.
5. Briefly explain, what is the teacher doing and what are the students doing in this picture?

Teacher walking around, checking student work, directing inquiry activities.

Students doing hands-on lab activities in groups or pairs, recording in notebooks, often moving about the classroom.
Image 4.2

*Drawing and Description by Teacher A and During 2021.*

![Drawing](image)

10. Briefly explain, what is the teacher doing and what are the students doing in this picture?

- **Teacher:** mostly stationary, demo + lecture
  - from front of class

- **Students:** in seats, very little movement about the room, distanced, working individually

It is clear from the artwork and descriptions that the perceived instruction moved from less teacher-centered in 2019 to more teacher-centered in 2021. In 2019, the teacher is “directing” student work. In 2021, the teacher is using “demo and lecture” from the front of the classroom. In 2019, students are working collaboratively “in groups or pairs”. In 2021, students are working “individually”.

In Image 4.3, the teacher description clearly indicates a more teacher-centered approach on the computer during virtual instruction. While students are still conducting hands-on activities from home, the hands-on component was “following online teacher instruction/direction.” The teacher appears to have students together in one whole-group meeting as opposed to in breakout rooms to work collaboratively.
Image 4.3

*Teacher A Teaching Virtually During the 2020 School Year.*

8. Briefly explain what the teacher is doing and what are the students doing in this picture?

Students working from home, doing hands-on lab activities alone at kitchen table, following online teacher instruction/direction.

Teacher speaking/demo online from home, viewing students through virtual meetings (Google Meet).

Not all teachers had to switch to virtual instruction during the 2020-2021 school year. After reviewing all drawings, 71% of respondents taught virtually during the 2020 school year. Image 4.4 shows Teacher B’s instruction during the fall of 2019. Image 4.5 shows Teacher B’s instruction during the fall of 2020.
Dilemma theory will be used to interpret these data further in Chapter 5. For this moment, it is interesting to note that the teacher moved students from a student-centered approach to a teacher-centered approach, with the teacher circulating and “observing” students in 2019 to “pushing out” work to students from the front of the room and them working individually to complete it.
A one-way ANOVA was conducted to determine if there were any differences between the grade-bands on the DASTT-C. The results of the ANOVA are represented in Table 4.3. The mean DASTT-C score in 2019 was 4.47 (as discussed earlier and shown in Table 2).
below shows that the average score for classrooms in each grade-band was similar because they weren’t statistically different from each other. In 2019, there were no significant differences among the four grade-bands (p < 0.921). The mean DASTT-C score in 2020 was 7.36 (as discussed earlier and shown in Table 2). Table 4.3 below shows that the average score for classrooms in each grade-band was similar because they weren’t statistically different from each other. In 2020, there were no significant differences among the four grade-bands (p < 0.892). The mean DASTT-C score in 2021 was 5.59 (as discussed earlier and shown in Table 2). Table 4.3 below shows that the average score for classrooms in each grade-band was similar because they weren’t statistically different from each other. In 2021, there were still no significant differences among the four grade-bands (p < 0.778).

Table 4.3

\textit{One-Way ANOVA Comparing DASTT-C Score Among Grade-Bands}

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>Between Groups</td>
<td>3.855</td>
<td>3</td>
<td>1.285</td>
<td>0.163</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>940.795</td>
<td>119</td>
<td>7.906</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>944.650</td>
<td>122</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2020</td>
<td>Between Groups</td>
<td>3.892</td>
<td>3</td>
<td>1.297</td>
<td>0.206</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>700.490</td>
<td>111</td>
<td>6.311</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>704.383</td>
<td>114</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2021</td>
<td>Between Groups</td>
<td>10.169</td>
<td>3</td>
<td>3.390</td>
<td>0.365</td>
</tr>
<tr>
<td></td>
<td>Within Groups</td>
<td>1187.740</td>
<td>128</td>
<td>9.279</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1197.909</td>
<td>131</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The ANOVA indicates that there were no statistically significant differences between how student-centered teachers perceived their instruction to be at the K-2, 3-5, 6-8, or 9-12 grade-band for 2019, 2020, or 2021. Because there is no statistically significant difference, no post-hoc data analysis was conducted. Quantitative analysis showed that K-12 classrooms were
perceived as largely student-centered in 2019, with a mean score of 4.47 on the DASTT-C reported by teachers. The finding that K-2 classrooms are not perceived to be more student-centered than high school classrooms contrasts with other research findings using the DASTT-C (Akkus, 2013; Markic & Eilks, 2012; Markic et al, 2006).

The series of figures below demonstrates similarities in diagrams and descriptions across the grade-bands pre-pandemic. Image 4.6 is from a K-2 classroom, Image 4.7 is from a 3-5 classroom, Image 4.8 is from a 6-8 classroom, and Image 4.9 is from a 9-12 classroom. Key words in teachers’ descriptions include “collaborating” and “investigating,” showing a strong focus on being student-centered at all grade-bands.

**Image 4.6**

*Instruction in a K-2 Classroom in 2019*

---

i. Briefly explain what the teacher doing and what are the students doing in this picture?

Students work in partners or groups to investigate a lab about magnets. Shared supplies, desk space. Teacher can “roam the room” after lab demo. Helps, interacts, instructs individual students and groups.
Image 4.7

*Instruction in a 3-5 Classroom in 2019*

Briefly explain what is the teacher doing and what are the students doing in this picture?

Investigating, exploring, collaborating, discovering. 

Guiding, encouraging, prompting, supporting, clarifying, misconceptions.
i. Briefly explain, what is the teacher doing and what are the students doing in this picture?

Teacher is moving around the room, stopping near students to discuss with them. An extra lab space is available to spread out and work on labs. Students are collaborating and working together.
Considering Student Population Demographics

Pearson’s correlations were conducted to determine whether there is a relationship between student population demographics and the perceived student-centered nature of instruction. “Correlation analysis is used to describe the strength and direction of the linear relationship between two variables” (Pallant, 2020, p. 135). The results show that there is, in this case, no significant correlation between student demographics and the nature of science instruction. Table 4.4 shows that the correlation coefficient between percent of the student population that receives free and reduced lunches and the score on the DASTT-C is -0.019 (significant at p < 0.826). “A perfect correlation of 1 or -1 indicates that the value of one variable can be determined exactly by knowing the value on the other variable…a correlation of 0
indicates no relationship between the two variables. Knowing the value on one of the variables provides no relationship between the two variables” (Pallant, 2020, p. 135). The slightly negative correlation coefficient of -0.019 indicates that there is almost no predictive relationship between the percent of the population that receives free and reduced lunches and the perceived student-centered nature of classrooms. Therefore, wealthier and poorer students being taught with this teacher population receive similar instruction.

**Table 4.4**

*Correlation Between Student Body Wealth and DASTT-C Score*

<table>
<thead>
<tr>
<th>Percent Free and Reduced Lunch</th>
<th>Pearson Correlation</th>
<th>1</th>
<th>-0.19</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td></td>
<td>0.826</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>133</td>
<td>133</td>
</tr>
<tr>
<td>Average DASTT-C Score</td>
<td>Pearson Correlation</td>
<td>-0.19</td>
<td>1</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>0.826</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>133</td>
<td>133</td>
</tr>
</tbody>
</table>

Table 4.5 shows that the correlation between the percent of non-white students (as reported by schools) and the score on the DASTT-C is 0.064 (significant at p < 0.464). While a little higher than the previous data in Table 4.4, the correlation coefficient of 0.064 indicates that there is almost no predictive relationship between the percent of the population that receives free and reduced lunches and the perceived student-centered nature of classrooms. Therefore, white and non-white students being taught with this teacher population receive similar instruction.

**Table 4.5**

*Correlation Between Percent of Non-White Students in the Population and DASTT-C Score*

<table>
<thead>
<tr>
<th>Percent Non-White Students</th>
<th>Pearson Correlation</th>
<th>1</th>
<th>0.064</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td></td>
<td>0.464</td>
</tr>
</tbody>
</table>
The correlations here indicate that student demographics are not related to teacher’s perceived choice of instructional method either before the pandemic or after the onset.

**Summary**

The results of this study provide evidence that science teachers’ perceptions of their instruction shifted during the pandemic. Before the pandemic, teachers perceived their classrooms to be very student-centered, showing that this sample of the science education community has moved away from teacher-led and direct instruction methods to more collaborative instruction where students are more actively involved in the learning. Further, the results showed no significant correlation between some demographic qualities of the student population and how student-centered instruction is. Finally, the results indicate no significant differences between grade level and nature of science instruction. The next chapter will explore the dilemmas teachers experienced that shifted instruction to be more teacher centered.
Chapter 5 – Discussion

The present study analyzed the state of science education before and during the COVID-19 pandemic in the United States as perceived by volunteer teachers who attended the NSTA regional conferences in 2021. In Chapter 4, I showed that, of the population studied, classrooms were largely perceived to be student-centered before the onset of the pandemic. Following the onset of COVID-19, instruction was perceived to become significantly more teacher-centered but have begun to become more student-centered as teachers return to in-person instruction and COVID-restrictions are eased. However, classroom teachers have not completely returned to their pre-pandemic pedagogies.

In this chapter, I will analyze the dilemmas teachers experienced before and during the pandemic by applying Mark Windschitl’s dilemma theory (Windschitl, 2001). The chapter will be written in four sections, corresponding to the years analyzed in data collection and followed by suggestions for future research and steps school leaders can take to move science instruction forward. I will show that in 2019, teachers demonstrated mostly conceptual and pedagogical dilemmas when attempting student-centered instruction K-12. I will then show that, during the first year of the pandemic in fall of 2020, teachers experienced all of the dilemmas outlined by Windschitl plus additional dilemmas: an emotional dilemma and a “pandemic dilemma.” Finally, I will show that, in 2021, teachers still experienced many of the dilemmas present in 2020, leading them to perceive their instruction to be more teacher-centered than before the pandemic.

Before moving on, it is important to note that the dilemmas teachers experienced will not all be visible using the Draw-A-Science-Teacher tool. Windschitl (2001) argues:

Distilling the ‘raw experiences’ of constructivist teachers into four categories of dilemmas emphasizes the multiple layers of concerns that they must address in their working lives. These categories help us not only to appreciate the complexity of
constructivism in practice but also to identify key aspects of teachers’ experiences that influence whether progressive pedagogies are likely to survive in their classrooms. (p. 157)

In short, constructivism is a messy and multi-faceted endeavor. Therefore, it is not likely completely captured with a simple drawing a teacher makes. Therefore, it was important to add the qualitative data from teacher interviews. The interview transcripts added color to the drawings and shed light on other complexities surrounding the experiences of teachers. Interestingly, the interview data also uncovered contradictions in what teachers are reporting in drawing and what they report doing in the classroom, lending credence to the argument that these drawings are how teachers perceive their instruction.

Dilemmas in Science Education Pre-Pandemic

As discussed in Chapter 4, teachers reported using predominantly student-centered instruction. This finding was true across all grade-bands, which contrasts with other findings in the field (Akkus, 2013; Markic, 2012; Markic et al., 2006). While the quantitative analysis shows that teachers reported mostly student-centered classrooms, interviews suggest that teachers were possibly drawing classroom instruction that occurred less often than is desirable. Further, an analysis of the drawings provided by all participants as well as interviews with select participants reveals that teachers encountered conceptual, pedagogical, and political dilemmas while attempting student-centered instruction.

Quantitative analysis showed that K-12 classrooms were perceived as largely student-centered in 2019, with a mean score of 4.47 on the DASTT-C reported by teachers. While most participant interviews aligned with the drawings teachers had made, the following excerpt suggests that some teachers might be representing students in groups “doing a lab,” but that
doesn’t necessarily mean that’s what they’re doing most of the time. When asked to describe their instruction in 2019, Catholic middle school teacher Mandy said:

I had the textbook up on the smartboard. I would have the kids sitting with the book open. I would paraphrase what was going on. I had 16-20 kids in the classroom. They were me presenting and them sort of absorbing. If there was time we would do a lab.

When asked what percent of the time students were doing a lab, the Mandy replied:

Pre-Covid? I mean, I’d say a lot, so maybe like 25%? It’s not all hands-on. Maybe a pre-lab day, the day where they’re doing the lab, and then conclusions. They would always have to do a graph with it.

The type of classroom instruction Mandy told me about clearly indicates instruction that is “on” students and not “with” students according to Neumann’s 2013 student-centered learning framework and would be more indicative of a higher score on the DASTT-C. It is interesting to wonder whether the location of teacher survey completion and interview completion played a role in the way teachers reported their classroom instruction. For example, it is possible that simply being at a science teaching conference primed teachers to focus more on representing the parts of their instruction that are student-centered.

While the drawings of teachers overall indicated perceived instruction that was very student-centered, teachers still experienced conceptual, pedagogical, and political dilemmas, all of which were indicated by teachers in both drawings and interviews. The dilemmas teachers were experiencing are in line with the challenges facing equitable science education identified by the National Academies of Sciences, Engineering, and Medicine in the Call to Action for Science Education (2021).
**Conceptual Dilemmas**

Conceptual dilemmas are defined as teachers “grasping the underpinnings of cognitive and social constructivism reconciling current beliefs about pedagogy with the epistemological orientations necessary to support a constructivist learning environment” (Windschitl, 2001, p. 133). Conceptual dilemmas most frequently showed up as teachers at the center of instruction using some form of lecture, book instruction, doing a mini-lesson before the lab, or “direct instruction.” Learning that was presented to students and then followed by a “lab” was a common representation, as seen in Image 5.1 below.

**Image 5.1**

*Conceptual Dilemmas Indicated in DASTT Drawings*

Pedagogical dilemmas are defined by Windschitl (2001) as “honoring students’ attempts to think for themselves while remaining faithful to accepted disciplinary ideas; developing deeper knowledge of subject matter; mastering the art of facilitation; managing new kinds of discourse and collaborative work in the classroom” (p. 133). Pedagogical dilemmas assume that
teachers are attempting student-centered instruction but are challenged with how to facilitate student thinking and collaboration.

During an interview, Georgia, a high school teacher, described instruction that demonstrated grappling with what it means to have a constructivist classroom under a pedagogical dilemma. In Georgia’s drawing, seen in Image 5.2, they have students working in groups, but clearly have the teacher at the front of the room in front of a whiteboard and with a computer.

**Image 5.2**

*Pedagogical Dilemmas Indicated in DASTT Drawings*

When asked what was happening in the diagram, Georgia responded, “I would throw out a question and have them come up with an answer in the group and then share for the entire class.” In this situation, the teacher is demonstrating an understanding that students should be working on the problem together and honoring students’ attempts to think for themselves, but still positions the teacher as the holder of accepted disciplinary ideas and questions by being at the front of the room, requiring students to respond to the teacher, and the teacher being the one to pose the question.

**Political Dilemmas**

Windschitl (2001) defines a political dilemma as a teacher “confronting issues of accountability with various stakeholders in the school community; negotiating with key others
the authority and support to teach for understanding” (p. 133). Bassock et al. (2016) found that only 1 in 5 early elementary teachers reported teaching science every day where nearly 9 out of 10 of those same teachers reported teaching math and literacy daily. Other researchers have found that instructional time allotted for science in elementary school has declined since No Child Left Behind (Blank, 2012; Griffith & Scharmann, 2008; McMurrey, 2008). This is likely due to the increased focus on standardized testing and mandated federal reporting structures that do not include science or social studies (Diamond & Spillane, 2004; Marx & Harris, 2006). Curran and Kitchin (2019) found that increasing time for science is one factor that can improve students’ performance on science assessments.

In this study, some teachers indicated challenges at the elementary level with having time for science. Darryl, a teacher at a high poverty elementary school, demonstrated that their instruction was very student-centered, as seen in Image 5.3 below.
Darryl then indicated in both writing on the DASTT and in the follow-up interview, that they were breaking the rules by engaging students in science instruction. Beneath their drawing on the DASTT, Darryl wrote, “This was not a regular occurrence – in my district, science instruction for kids at the elementary level is seen as non-essential. Technically, I was violating the school rules by using reading time for teaching science.” When asked about this in the follow-up interview, Darryl said,

Ok well first I should say that, where I teach, uh, science is not valued. So officially where I am today, the word science does not appear on the daily schedule for the building… The admin weren’t fans of us doing science because unfortunately the district, and you may see this in other places, the mentality was we only teach reading and math
in elementary school, that’s the only, that’s what counts because that’s what is tested on
the end of the year Smarter Balance Test.

Clearly, time for science instruction is a well-documented political dilemma that occurs
in science classrooms, particularly at the elementary level. The sample size for elementary
classrooms (25 K-5 total) was quite small compared to the middle school (50 total) and high
school (56 total) samples. I wonder if more teachers would have indicated a political dilemma if
the elementary sample size were larger.

In summary, teachers across K-12 indicated predominantly exploratory student-centered
classrooms in 2019, before the COVID-19 pandemic began to impact education systems in the
United States. While teachers drew themselves as student-centered instructors on the DASTT,
some interview data suggests that the drawing may not always provide a true picture of what is
happening in a classroom most of the time. Both DASTT drawings and interview data suggest
that teachers grappled with conceptual, pedagogical, and political dilemmas before the onset of
the pandemic. The next section of this chapter will focus on dilemmas teachers experienced in
the fall of 2020 during the first full year of teaching during the COVID-19 pandemic.

**Dilemmas in Science Education in the Fall of 2020**

As discussed in Chapter 4, teachers reported more teacher-centered environments during
the 2020 school year and the first full year of the COVID-19 pandemic in the U.S. Instruction
shifted from an average score of 4.47 on the DASTT-C in 2019 to an average of 7.36 in the fall
of 2020. This section will show that teachers experienced each of the dilemmas outlined in
Windschitl’s (2001) dilemma theory as they worked to engage students with science instruction.
However, this section will also show how teachers battled another dilemma: an emotional
dilemma that I will call “The Pandemic Dilemma” and that significantly impacted teachers’ ability to be successful teachers during the height of the pandemic.

Conceptual dilemmas were present in the 2019 data, as was discussed above. However, conceptual dilemmas were obviously a small portion of the dilemmas teachers were experiencing because the DASTT-C would have been much higher pre-pandemic if teachers in this sample were struggling with conceptual dilemmas. Therefore, it is fair to say that teachers that shifted towards more teacher-centered instruction did so because of other dilemmas they were experiencing. While pedagogical and political dilemmas were evident in the 2019 data set, cultural dilemmas were not. However, in the 2020 dataset, cultural dilemmas occupy many of the teachers’ drawings and descriptions.

**Pedagogical Dilemma**

In the interviews, many teachers described a shift to virtual instruction or instruction where students were spaced very far apart. In their descriptions, it is clear that teachers were grappling with how to maintain student-centered science experiments in the face of these challenges. Navigating these shifts is a pedagogical dilemma because teachers are trying to work out how to create an alternative method to students engaging in first-hand experiences, which they were doing before the pandemic. In their interview, middle school teacher Caitlyn said,

> You can’t do hands on science online. I tried to some things with a document camera and so we would do it, but then people couldn’t see, it was blurry, it was like a nightmare. No technology worked. Kids couldn’t log on.

Other teachers, myself included, tried to send materials home with kids or to get students to engage with materials they had at home. Image 5.4 shows physics teacher Georgia’s virtual classroom. In their interview, Georgia lamented,
I tried to find hands-on things I could send to them. We did a few things like that, but to do that you have to like already send home with them a graduated cylinder and some way to weigh their stuff and it was very materials intensive. And then I discovered that what we could do with that was not much.

Image 5.4

*Students engaging with materials at home*

---

8. Briefly explain, what is the teacher doing and what are the students doing in this picture?

**Students working from home, doing hands-on lab activities alone at kitchen table, following online teacher instruction/direction.**

**Teacher speaking/doing online from home, viewing students through virtual meetings (Google Meet).**
By Windschitl’s 2001 definition, pedagogical dilemmas can occur when teachers must work harder to make student-centered instruction occur. In this case, many teachers made a move from student-centered to either lecture or demonstration during the pandemic because they experienced the increased challenges of finding appropriate resources or materials challenges. Many teachers moved to doing science by demonstration because, if they were in person, teachers were not allowed to let students share materials or, if they were online, could not get students many materials for students to use at home. Image 5.5 shows a teacher’s classroom with a demo table and the teacher at the front of the room because students were unable to share anything and the teacher could not circulate.
Cultural Dilemma

Cultural dilemmas can arise when teachers are struggling to establish a culture of communication between students. An open and dialogic classroom culture is necessary for students to be engaged with the decision making and meaning making that are tenets of the student-centered classroom (National Research Council, 2012). Cultural dilemmas were abundant in the classrooms drawn by teachers in this study in the 2020 school year. Caitlyn, a
majority minority middle school teacher, discussed how students would not communicate with each other:

> When we came back in August we came back to school and kids had the choice to stay online at home or come in. They couldn’t do both. That was a nightmare. I’m not tech-savvy whatsoever. It was every day all day a big computer mess. The kids would login and would play games. They weren’t paying attention at all. Once I finished attendance they would just shut down or stay there and be silent. They wouldn’t participate.

Some teachers tried to encourage students to talk to each other by placing them in breakout rooms. For some teachers, this worked, but for many, students did not use the breakout rooms effectively and would instead work alone. Georgia wrote:

> I tried breakout rooms. And honestly they would go into the breakout rooms and not talk to each other. So I would try to pick one student who was very consistently there and also would occasionally turn the camera on. So I would ask them, would you lead this? But they don’t have any leadership skills.

Liliana, a high school suburban teacher said:

> Breakout rooms didn’t work for me. Putting them in small groups, students were so disengaged that they wouldn’t even talk to each other…. If you would pop into the breakout rooms, they weren’t talking to each other. The collaboration was not there and that’s one of the ways they learned best. So that part was missing.

Establishing a culture where students were comfortable talking to each other, and processing online was a very clear challenge for teachers. This challenge forced teachers into a dilemma: do they continue to try to get students to have group discussion, or do they settle so at least one or two students participate? Many teachers resorted to more direct forms of teaching or
a back and forth with just one or two students in order to quickly increase engagement. Darryl said, “the lesson is completely direct instruction. There will not be discussion among students, only between the teacher and individual students.”

**Political Dilemma**

Establishing a classroom culture that fosters student engagement with the material through a computer is challenging enough, but adding in the political mandate that students are not required to turn on their cameras adds another layer of complexity and is a political dilemma teachers experience. Many school districts did not mandate that students turn on their cameras during class citing “Zoom fatigue” (Leighton, 2021) or privacy and equity issues (Torschia, 2021). While these student needs are very real, “invisible” students is the primary dilemma teachers indicated when teaching virtually in the 2020 school year. Rebecca, a middle school suburban teacher explained how teachers were forced to follow the political mandate at the expense of more robust instruction:

One thing I found very frustrating was that people who do not have contact with kids were saying things like, you have to lower your standards. Like, the superintendent of [my] county actually sent a memo to teachers saying lower your standards, like those exact words, which was upsetting and frustrating to me. I feel people are like you have to cut kids a break and that’s lowballing what kids can do…Kids can do hard things. I feel like the adults were saying to them “this is too hard”. It’s not, it is hard, but there were other adults around them saying it’s too hard, just you know, do the minimum. I know they would sign on, turn their cameras off and walk away from the computer. Or they might be in front of the computer watching Netflix or some other thing. Trying to get them engaged with me at some level was very challenging.
It is very easy to understand that children experienced extraordinary amounts of stress during the pandemic and this stress could cause them to want or need to “tune out” or distract themselves. The challenge becomes when teachers are accountable for supporting those students or helping them make academic progress. Holding students accountable while their cameras are off is incredibly challenging for the teacher. It is also difficult for the teacher to build any relationship with a student that they cannot see or meet, thereby making it impossible for the teacher to provide any emotional supports for students who may need it. Images 5.6 and 5.7 show teachers’ drawings where they could not connect with students.

**Image 5.6**

*A teacher explaining that students’ cameras were off during instruction.*
Another political dilemma some teachers experienced in science education during the pandemic is a further decreased amount of time allotted for science instruction. Darryl said:

Before we went back to classrooms, we were meeting four days a week and only a couple hours a day. What happened was, the powers that be were saying, look, it’s just reading and math instruction. You should really just be doing reading and math instruction. This last year [in 2020], we only did science about five percent of the time.

One respondent, Sonja, worked in a partner program with elementary schools in the area. Sonja demonstrates how much science instruction was cut back at the elementary level during the pandemic:

Before the pandemic, I saw 1200 kids a quarter [for a full day]. And once we started doing virtual, we were only an hour at a time and then we only offered two per day. And it tended to be that teachers did not sign up. We saw far fewer kids than we did before.

A political focus on reading and math forced elementary teachers in particular into a political dilemma. Do I use some of what little time I have to engage students in something that brings them joy and increases their engagement, or do I follow the protocol and focus primarily on reading and math?
**The Existential Dilemma**

Decreased emphasis on science instruction, the ability for students to be “invisible,” and a fundamental shift in the way teachers teach science – the subject they love – all combined into something akin to an existential dilemma for teachers. A large number of teachers drew or wrote about the emotional fatigue they experienced as they navigated this new landscape during COVID-19 and this presented a dilemma of its own. Some teachers drew diagrams of them teaching with sad or angry faces.

Image 5.8 shows a sad teacher and how not interacting with students impacted them and image 5.9 shows a depressed teacher at their computer. The caption from Image 5.8 is:

The teacher is sadly sitting in a remote room away from students. The teenagers all turn off their cameras even if I encourage them. If they do have the camera on they look so sad in their hoodie sweatshirt forlornly sitting on their bed – no group work on microscopes. Everything online. I want to quit teaching – this is no fun. I love children and find energy interacting with them.
Image 5.8

A sad teacher during 2020

7. Draw a picture of you as a science teacher at work in the fall of the 2020-2021 school year.

8. Briefly explain, what is the teacher doing and what are the students doing in this picture?

The teacher is sadly sitting in a remote room away from students. The teenagers all turn off the cameras even if I encourage them. If they do have the camera on they look sad in their hoodie sweatshirt, solemnly sitting on their bed - no group work on microscopes. Everything online I end up quitting teaching - this is no fun. I lost children and fund every interacting with them.
Image 5.9

Sad teacher at a computer in 2020

7. Draw a picture of you as a science teacher at work in the fall of the 2020-2021 school year.

8. Briefly explain, what is the teacher doing and what are the students doing in this picture?

Being exhausted. 75% of our students quit and did not return. Remote virtual learning was a horrific joke.

Other teachers showed their distress by writing a description of how terrible teaching this way is. The last line on Image 5.10 clearly shows this teacher in emotional distress.
Image 5.10

Teacher instruction and emotional dilemma in 2020

8. Briefly explain, what is the teacher doing and what are the students doing in this picture?

I am sharing my screen with a group of black boxes on Zoom that may or may not have students sitting on the other side of Zoom listening.

I'm sitting at the desk in my loft & my dog is snoozing in his bed near me.

My dog had a very happy fall last year.

The picture that would have shown up some evenings would have been me on the floor crying.
One teacher (Image 5.11) said teaching during the pandemic was a “different form of hell” near the end of their description.

**Image 5.11**

_HyFlex teaching_

---

8. Briefly explain, what is the teacher doing and what are the students doing in this picture?

---

The caption here says:

Students are facing w/b [whiteboard] with masks as well as zooming online using Google CR [classroom] as a learning tool. Assignments posted virtually in person. Students used Chromebooks to submit pictures or type in answers to worksheets or “forms” w/ multiple choice. Scanned worksheets were also used. It was a different form of Hell.

This teacher was not just teaching online but was teaching simultaneously to students in person and online. The teacher shows that they are wearing an earbud and communicating with
students that are online while simultaneously circulating among students that are in person.

Clearly, this teacher found HyFlex instruction to be incredibly challenging.

Throughout the pandemic, teachers were asked to navigate teaching in a variety of improbable contexts. Image 5.12 shows a teacher that was asked to teach to two different rooms of students while standing in between both classrooms and giving instructions.

**Image 5.12**

*Teaching to two rooms of students simultaneously*

Many teachers (Image 5.13) also indicated that they were teaching students online as well as managing their own children at home. I found myself in this same situation while I was teaching in 2020.
Hargreaves (1998) showed that teaching is a socially situated process that requires engaging with emotional experiences.

Emotional labour is an important part of teaching, and in many ways, a positive one. For many teachers, it is a labour of love. Classrooms and schools would be (and sometimes are) barren and boring places without it…it is also important to recognize that emotional labour also exposes teachers, making them vulnerable when the conditions of, and demands on, their work make it hard for them to do their “emotion work” properly. (p. 322)

In his seven-point framework regarding teaching and emotions, Hargreaves says that, “teachers’ emotions are rooted in and affect their selves, identities, relationships with others and teachers’ emotions are shaped by experiences of power and powerlessness” (p. 319). During the
pandemic, science teachers experienced a loss of power and relationships with students, creating a space where teachers were suffering emotionally while trying to maintain their student-centered classroom environments. Building on this work, Shirley et al. (2020) showed that, “educators’ well-being is likely to prosper in environments…that generate positive emotion and satisfaction among educators by enabling them to accomplish deep and morally inspiring purposes over which they exert shared professional control” (p. 10). Teachers in this study clearly show feelings of loss of control and a loss of relationships with their students. Not only do these emotional challenges impact teachers and their sense of job satisfaction, but Keller and Becker (2021) showed that teachers’ emotions and emotional authenticity impact student emotions and success.

It is clear that teachers experienced more than just the four dilemmas outlined by Windschitl when trying to teach in the 2020 school year. Teachers worked hard to surmount the varying situations they were asked to teach in and to show up for students every day. It is also clear that teachers experienced an emotional dilemma, mostly generated because of limitations due to the pandemic, and that dilemma has implications for teachers and students alike. Teachers were faced with showing up for students or caring for their own selves. Because of this emotional dilemma, it is likely they were unable to persevere in finding new ways to keep classrooms student-centered while emotionally drained. The next section of this paper looks at the state of science education in the 2021 academic school year.

Dilemmas in Science Education in the Fall of 2021

The quantitative data analysis in chapter 4 of this study shows that the classrooms in this population were mostly student-centered before the COVID-19 pandemic (DASTT-C average of 4.47), shifted to much more teacher-centered during the first full year of the pandemic (DASTT-C average of 7.36), and then in the fall of 2021 began to move back towards student-centered
(DASTT-C average of 5.59). The qualitative descriptions on the surveys coupled with teacher interviews show that teachers still experienced dilemmas in every category, but the pandemic emotional dilemma has subsided for teachers. However, new political and cultural dilemmas arrived as schools tried to combat surges in student and teacher illness and students re-acclimated to in-person instruction.

In 2021, many teachers are reporting that their instruction has gone back to normal. In fact, for their drawings, many teachers wrote something like “see 2019 drawing” to avoid having to take the time to re-draw their classroom. Image 5.14 shows an excited teacher’s drawing of their classroom after having been completely distanced from their students in the 2020 school year.

**Image 5.14**

*In-person instruction shifting back to student-centered*

9. Draw and upload a drawing or sketch of you as a science teacher at work in the fall of the 2021-2022 school year.

![Drawing of a classroom](image)

10. Briefly explain, what is the teacher doing and what are the students doing in this picture?

*Back in business, with no masks!*  
*Teacher is allowed to move freely.*  
*Ss are allowed in groups! We are even allowed back in the lab.*
Interviews of some teachers showed that they were also excited to be heading back to more student-centered instruction. In their interview, middle school teacher Eva said:

I kind of feel like it is pre-COVID. We are back in school. We are all wearing masks, we sit together, the kids are sitting in groups and we can work together. I don’t feel any restrictions on what I can do.

Participant Caitlyn moved back to student-centered instruction because it made their students happier, but this was against the wishes of the administration. Caitlyn said:

We are back to do doing hands-on stuff. The district says we shouldn’t, but I don’t care. I’m done… Kids are happier this year doing hands-on. Everyone is social. Everyone is talking. Everyone is doing work. Last year [online] it was like pulling teeth.

In some places, instruction has shifted back toward student-centered. In other places, however, teachers wanted to make the shift back but experienced multiple dilemmas in trying to do so.

**Conceptual Dilemma**

While many classrooms in this study were shifting back towards student-centered, some teachers continued to struggle with student-centered modalities as the primary method of student instruction. The majority of the teachers who indicated a teacher-centered instructional approach in 2019 returned to that instructional approach in 2021. Interestingly, there were a few teachers in the sample that had a very teacher-centered mode of instruction in 2019 and had a very student-centered approach in 2021. One teacher’s classroom drawings are shown in Images 5.15 and 5.16.
Image 5.15

Teacher-centered in 2019

4. Draw a picture of you as a science teacher at work in the fall of the 2019-2020 school year.

5. Briefly explain, what is the teacher doing and what are the students doing in this picture?

Teacher lecturing at the board
Students working at desks in an L shape
Student-centered in 2021

9. Draw and upload a drawing or sketch of you as a science teacher at work in the fall of the 2021-2022 school year.

10. Briefly explain, what is the teacher doing and what are the students doing in this picture?

It is evidence from the data that some teachers were able to move out of the conceptual dilemma and embrace student-centered instruction.

Cultural Dilemma

With a move back to the cooperation that is foundational in student-centered instruction however, many teachers expressed a cultural dilemma because students were struggling to work well together. In a Pew research article, Christine Vestal (2021) notes that students have come back to school after the first year of the pandemic with a wealth of psychological issues: “The grief, anxiety and depression children have experienced during the pandemic is welling over into classrooms and hallways, resulting in crying and disruptive behavior in many younger kids and increased violence and bullying among adolescents.” These challenges translate to cultural
dilemmas in the classroom. For a science teacher, the dilemma is whether to have students share materials and work cooperatively in groups or to stick with the safer and easier teacher-centered instruction and avoid managing disruptive and uncooperative behaviors.

Image 5.17 shows an elementary classroom in 2019, where the teacher is describing students working productively in the STEM lab. Image 5.18 shows the classroom of the same elementary teacher in 2021. This teacher’s drawing shows where students typically did not struggle with behavior challenges are now really struggling. In the drawing, one student can be seen screaming, two students have angry faces, and one student is completely frazzled.

Image 5.17

*Peaceful elementary students in the STEM lab in 2019*

5. Briefly explain, what is the teacher doing and what are the students doing in this picture?

   *Students making things in our STEM LAB*
Image 5.18

Stressed elementary students in the STEM lab in 2021

These challenges are happening outside of the elementary classroom as well. Georgia, a middle school teacher, expressed their concern about student behavior:

“It’s um, well, uh the kids don’t remember how to behave in a classroom…Um, a lot of my kids can, with a partner, work together. If you add more than that, they have totally forgotten how to do that. [Instead], they pick on one person [in the group] to be annoying to them.

Further, some teachers indicated that students came back from the pandemic in 2021 less independent and needing more supports than pre-pandemic. Image 5.19 shows a high school teacher indicating that students needed more supports. In the caption, the teacher says, “Similar to pre-pandemic, but students are much less independent and need more guidance. They also seem less likely to ask questions. Maybe because of lost year or because of the masks making me seem more threatening.”
Students need more support in class

It is easy to imagine many teachers avoiding these challenging behavioral situations by using a more teacher-centered form of instruction. Students need explicit instruction on social skills in cooperative group work (Johnson & Johnson, 1990) and social skill instruction takes a significant amount of time and work on the part of the teacher. As I will show in the next section, many teachers in the 2021 school year were having to prepare multiple lesson plans for the same topic to reach students through multiple modalities. The demand for teacher’s time both in and out of the classroom may make it challenging to teach or re-teach social skills to students so they can work in groups in science class.
Political Dilemma

Some districts were still placing strict limitations on what science teachers could do. In the survey and in interviews, teachers expressed challenges with being forced to keep students 3 – 6 feet apart, mandates about providing instruction for students both in person and virtually simultaneously, and mandates to keep students on computers for instruction.

Participant Georgia explained that the distancing mandate impacted how much cooperative work students are doing in their science class, “We do have a three-foot mandate and so it’s tough to work in a group if you have to stay three feet away from everyone else in the group. So I don’t have as many group activities as I used to.” Participant Liliana expressed similar challenges as they moved away from teacher-centered toward student-centered instruction in 2021:

I think it’s more at the beginning of the year I was more up front [of the room] and I’ve broken away from that. Kids are now collaborating a bit together. At least they can talk about the things that they’re doing. We do a lot of um, not as many labs, like microscope labs because we can’t have everybody gather. But manipulatives are coming back.

One participant’s drawings show how the mandates for social distancing impact their instruction. Image 5.20 shows this teacher’s completely student-centered classroom in 2019. Image 5.21 shows the same teacher’s classroom in 2021.
Other teachers struggled with the continued need to provide instruction for students that were joining their in-person classrooms virtually either all year or due to COVID quarantine.
protocols. Figure 5.22 is a drawing from a teacher that is exasperated by the need to teach in a hybrid method. The description says:

This is a hybrid class – what a challenge – you have to teach online and in person. This is an impossible task even with all the amazing online resources I found. You need to use different techniques for each method. You are simultaneously doing two different things and at times neither seemed to be working. Ugh!

**Image 5.22**

*HyFlex frustration*
Interview participant Eva expressed similar frustration:

There’s a lot more absences. That is one thing that kind of puts a damper on things. Kids are getting missed. There’s a lot more of that than in prior years. If they’ve come into a close contact. There’s a lot of COVID-related reasons why more kids are absent. That’s where I would feel it. I have lots of workarounds for that though because it’s always a problem, it’s just that this year it’s more of a problem.

In this data set, it is more common for teachers that express challenges with students being both in person and virtual to also be more teacher centered.

Finally, while looking through teacher drawings, I noticed a lot of pictures of teachers in 2021 where students are in person, but the students are on computers in the classroom. I asked participant Liliana about this and they said, “Our principal said to us you have to do everything digital. I don’t want you to go backwards, I want everything digital this year.” Liliana expressed the understanding that the principal did not want to pay for copies. It is possible that, like Liliana’s school, other teachers are being asked to keep student work digital. It is also possible that teachers became more comfortable with digital learning tools and continued to carry this through into the 2021 school year.

Summary

In 2021, teachers encountered many dilemmas. While the emotional dilemmas teachers experienced in 2020 do not seem to be present in 2021, new dilemmas have come to the forefront. Some teachers reverted back to the conceptual dilemmas they held before the COVID-19 pandemic impacted instruction. Other teachers experienced cultural dilemmas as students struggle to re-integrate into cooperative learning. Some teachers experienced political dilemmas stemming from forced social distancing, policies surrounding integrating absent and quarantined...
students, or mandates to use computers in place of hands-on science equipment. However, classrooms are shifting back towards student-centered instruction. In the final chapter of this dissertation, I will summarize the findings of this study, discuss limitations, and present thoughts on areas of future study.
Chapter 6 – Conclusions

This study reviews the experiences of a set of K-12 science teachers that taught throughout the COVID-19 pandemic. Volunteer teachers who attended the NSTA regional conferences in 2021 completed a survey detailing their experiences. The Draw-A-Science-Teacher-Tool was used to gather images of teachers’ experiences as they perceived them from the fall of 2019, the fall of 2020, and the fall of 2021 (Thomas et al., 2001). A modified checklist was used to score the teachers’ drawings on a scale from 0 to 13, with a zero being a completely student-centered classroom and a 13 being a completely teacher-centered classroom. A subset of teachers was then interviewed to provide context for their drawings. Interview transcripts were coded using Windschitl’s (2001) dilemma theory to explain the challenges teachers faced when attempting to provide student-centered instruction in their science classes throughout the pandemic. In this final chapter, I will summarize the results of the study and answer the research questions. I will also discuss limitations of the study as well as implications for future research.

Summary and Discussion of Results

The primary question addressed in this study was, in what ways did perceived student-centered science instruction change while the education community was experiencing a pandemic? The data from this study suggests that teachers largely perceived their instruction to be student-centered before the pandemic, more teacher-centered during 2020, and moving back towards student-centered in the fall of the 2021 school year. Analysis of teacher drawings from the DASTT combined with interview data show that teachers experienced Windschitl’s dilemmas to varying degrees throughout the pandemic and these dilemmas are likely responsible for the shifts in student-centered instruction. Analysis of teacher drawings and interview data
also shows that teachers experienced a new, existential dilemma, during the height of the pandemic in 2020.

**Conceptual Dilemma Over Time**

A teacher experiences the conceptual dilemma from Windschitl’s 2001 theory when they grapple with the concept of student-centered versus teacher-centered instruction. Teachers with this dilemma are “reconciling current beliefs about pedagogy with the epistemological orientations necessary to support a constructivist learning environment” (Windschitl, 2001, p. 133). In teachers’ drawings from this study, this often shows up as teachers placing lecture (direct instruction), reading, or some form of notes, mini-lesson, or presentation before students do a “lab.”

Although the DASTT-C scores show that overall, teachers’ perceived instruction was student-centered in the fall of 2019, the conceptual dilemma was still present. Many teachers described lecturing, using a mini-lesson before lab, and direct instruction as the primary modality of their classroom. In 2020, after the pandemic caused significant disruption to the United States’ educational system, far more teachers describe using a lecture, powerpoint, or reading as their primary modality. While the presence of these modalities increased, signaling a conceptual dilemma, many of these teachers did not demonstrate the conceptual dilemma because they were using student-centered constructivist instruction in their 2019 drawings. Therefore, other dilemmas must be in play.

**Pedagogical Dilemmas Over Time**

Pedagogical dilemmas are defined by Windschitl (2001) as “honoring students’ attempts to think for themselves while remaining faithful to accepted disciplinary ideas; developing deeper knowledge of subject matter; mastering the art of facilitation; managing new kinds of
discourse and collaborative work in the classroom” (p. 133). Pedagogical dilemmas assume that teachers are attempting student-centered instruction but are challenged with how to facilitate student thinking. A few of the questions Windschitl notes teachers might be grappling with when they experience this dilemma are, “Do I base my teaching on students’ existing ideas rather than on learning objectives?” or “What does it mean for me to become a facilitator of learning?” (Windschitl, 2001, p. 133).

In the drawings and interviews, the pedagogical dilemma often presented as teachers providing the questions of students’ study, posing the challenge, or modeling a procedure. In 2019 and 2021, pedagogical dilemmas often also showed up as students placed in groups, but the teacher talking or giving directions from the front of the room. In 2020, pedagogical dilemmas were exacerbated as teachers attempted to move their instruction from in-person to virtual. Teachers who were attempting student-centered instruction in 2019 were often at a loss for how to maintain that instruction during virtual instruction. In interviews, some teachers expressed trying to maintain this environment by sending materials home to students or doing demonstration on their own teaching screen but having to work much harder to continue to center students. Qualitative interview data shows that some of the teachers who attempted this gave up after some time because it was too difficult to maintain.

**Cultural Dilemmas Over Time**

Windschitl states that teachers who are grappling with cultural dilemmas are “becoming conscious of the culture of one’s own classroom.” Teachers who are grappling with cultural dilemmas might ask questions like, “How can we contradict traditional, efficient classroom routines?” and “Can I trust students to accept responsibility for their own learning?” Teachers grappling with cultural dilemmas may also express concerns over centering the “experiences,
discourse patterns, and local knowledge of students with varied cultural backgrounds” (Windschitl, 2001, p. 133).

In the drawings and interviews, cultural dilemmas frequently showed up as a lack of student discourse or a lack of students grappling with information. Cultural dilemmas were not evident in the drawings of teachers’ perceived instruction in 2019, nor did they surface in interviews. However, in 2020, as instruction shifted to primarily virtual or socially distanced, teachers seemed to be challenged to maintain discourse in their classrooms.

While some teachers were able to facilitate discussion, many teachers reported an inability to establish classroom culture online where students felt comfortable to engage in discourse. A large portion of teachers reported that students simply would not respond to prompts while on their computers. Some teachers in the study attempted to facilitate a culture of collaboration and discourse by assigning group work and placing students in breakout rooms. Many of these teachers reported that students were unsuccessful collaborating in these spaces and would often revert to independent work.

As classes returned to in-person in the 2021 school year, teachers reported far more cultural challenges than before the pandemic. Teachers’ drawings indicate that students returned to school with a number of social, emotional, and academic challenges that prevented them from engaging productively in student-centered instruction. Teachers in these situations were left to grapple with attempting to maintain student-centered instruction or to re-center the class on the teacher and to build their classroom culture from this place instead. Other teachers whose students returned to the classroom were faced with a number of political dilemmas when trying to re-establish student discourse as school leadership navigated the shifting health and safety demands placed on them.
Political Dilemmas Over Time

According to Windschitl (2001), teachers encounter political dilemmas when “confronting issues of accountability with various stakeholders in the school community” (p. 133). Teachers in this study expressed many political dilemmas as they continued science instruction through the COVID-19 pandemic, the first of which is enough time allotment for science.

In responses regarding both 2019 and 2021, teachers reported an inadequate amount of time for science, especially in elementary schools. One interviewee told how their school strongly discouraged the teaching of science in exchange for time spent on literacy and mathematics. In 2020, elementary science was often relegated to small portions of students’ academic days or to completely asynchronous work to allow use of synchronous class time for literacy and math instruction. Other respondents described places in 2021 where science instruction is placed at the end of the day and is rushed. In this case, the teacher indicates that her student-centered instruction remains incomplete from day-to-day: “Trying her best with a shortened timeframe at the very end of the day to squeeze in a knowledge building book, having the design process shortened the next day. Very hurried!”

Aside from time challenges, teachers also faced physical distancing mandates from the government and district leadership that hindered student collaboration during problem solving. In 2020, some teachers who wanted to send materials home to students attending virtually were unable to do so. Other teachers expressed that they wanted to put their students into breakout rooms to facilitate cooperative learning but were not allowed to leave students “unattended.” In classrooms where students were physically in school, teachers were often forced to stay at the front of the classroom. In turn, students were required to remain distanced, and in many cases,
completely facing forward. In many cases, teachers indicated that the passing of materials throughout the classroom was prohibited.

Some of these challenges remained into the start of the 2021 school year. Teachers were reporting strong limitations on cooperative learning environments and student contact with the teacher, each other, and even with materials. Because of these limitations and because some students were still virtual or hybrid throughout the fall of the 2021 school year, teachers were often required to keep students on computers within the science classroom instead of engaging with first-hand experiences. All of these limitations from outside forces caused teachers many to rely on more teacher-centered instructional methods.

The Existential Dilemma Facing Teachers

While we know from Windschitl’s dilemma theory that teachers experience dilemmas that sometimes prevent them from executing the most high quality and engaging instruction for students, perhaps the most telling finding from this study is the existential dilemma science teachers faced as they weathered the COVID-19 pandemic. Diliberti et al. (2021) showed that teacher stress and levels of burnout were high during the pandemic. This finding is corroborated by the data in this study. Teachers in this study demonstrated a strong feeling of being disconnected from students, stress from trying to engage students that were at times unreachable, and exhaustion from trying to engage in so many forms of instruction at one time.

Hargreaves (1998) wrote about the emotional labor teachers engage in to provide high-quality instruction. Shirley et al. (2020) also showed that educators’ well-being is deeply influenced by their sense of control and purpose. Teachers in this study were clearly struggling to find a locus of control and it may have impacted their sense of purpose, leading to the existential
dilemma. This dilemma led some teachers to wonder what the point was. As one teacher said, “remote-virtual learning was a horrific joke.”

Teacher burnout and emotional distress can have very real consequences for students in the classroom (Arens et al., 2016; Hoglund et al., 2015; Klusmann, 2008). During a pandemic when students are already struggling emotionally, receiving instruction from burnt-out teachers could possibly have an even larger impact. Further, teacher emotional burnout impacts their willingness to remain as teachers. A 2021 Rand Corporation study shows that nearly 25% of teachers surveyed were likely to leave their jobs after the 2020-2021 school year and that teachers reported the “mode of instruction” as a highest-ranked stressor (Steiner & Woo, 2021).

**Limitations of the Study**

“Limitations are potential weaknesses or problems with the study identified by the researcher…these limitations are useful to other potential researchers who may choose to conduct a similar or replication study” (Creswell & Guetterman, 2019). The following section enumerates several limitations of this study.

**Limitations with Sampling**

The study sample consisted of a very small number of teachers drawn from a large national teaching organization. While the effect sizes for the significance among the DASTT-C scores were large, the sample itself represents a very particular group of people. Therefore, generalizability of the results is limited. For example, it is possible that the sample of teachers that volunteered for this study are more highly trained on student-centered instructional practices as a result of membership in this teaching organization. Therefore, it is possible that their perception of their instruction is more student-centered than teachers who are not members of this study population.
While the study sample is a limitation, the results of this study are, in turn, also very illuminating when the sample population is considered. Because the teachers in this study seem to be highly motivated to seek professional development in their field, they could also be representatives that show how detrimental dilemmas are to achieving the vision of high-quality science instruction for students. Teachers in this study were influenced by conceptual, pedagogical, cultural, political, and existential dilemmas that affected their perceived instruction. It leads me to wonder how strongly these dilemmas impact teachers who are not armed with as much access to professional learning and a strong community.

**Limitations with Instrumentation**

The Draw-A-Science-Teacher-Test used in this study limits the scope of inferences that can be made about the results. First, the DASTT was designed to assess pre-service teachers’ beliefs, not necessarily actual practice of teachers. Even more caution must be exercised when interpreting the results because teachers were asked to make these drawings from memory over a more than two-year period. As a result, the drawings cannot be held as representing factual events that occurred but must represent teachers’ perception of their teaching.

Interpreting teachers’ diagrams also required a degree of inferencing on the part of the researcher while applying the theoretical framework. Careful attention was given to ensuring that the dilemma that was interpreted from the diagrams was consistent with the evidence statements Windschitl laid out in the framework. However, there was some grey in the interpretation as the framework was applied to the drawings. The researcher tried to maintain fidelity across all analyses by completing them in a short timeframe, maintaining memos, and cross-referencing with the dilemma categories of constructivism in practice while coding.
Implications for Further Research

The findings from this study answer the research questions, but also provide opportunities for further research. The foremost question to be studied is: Will the perceived student-centered instruction of the teachers in this study continue to shift back toward their pre-pandemic levels? If so, how long will that take? Shifts towards student-centered instruction in the science education community have been in progress since the mid-90’s. Further, the Next Generation Science Standards were adopted in 2013. Strong science education is critical for all students and even more so with the challenges our students will face. It will be important to understand whether science education recovers from the pandemic.

A second question these findings bring to mind is: Will student success in science learning be impacted as a result of the shifts that occurred during the pandemic? There is evidence from this study that there continues to be a focus on literacy and mathematics recovery at the expense of science education.

A third set of questions these findings raise is: What were the experiences of teachers in other subject areas? And, will the existential dilemmas teachers faced during the pandemic lead to a teacher shortage, especially in science education in the coming years? These questions will be important as we look to understand the long-term needs of schools and how best to support our teachers so we can achieve and maintain high quality instruction.

Conclusion

In their Call to Action, the National Academies of Sciences, Engineering, and Medicine (2021) write:

Science is an essential tool for solving the greatest problems of our time and understanding the world around us. Scientific thinking and understanding are essential for
all people navigating the world, not just for scientists and other science, technology, engineering, and mathematics (STEM) professionals. They enable people to address complex challenges in local communities and at a global scale, more readily access economic opportunity and, rein in life-threatening problems such as those wrought by a global pandemic. In this way, knowledge of science and the practice of scientific thinking are essential components of a fully functioning democracy. Science is also crucial for the future STEM workforce and the pursuit of living wage jobs. Yet, science education is not the national priority it needs to be, and states and local communities are not yet delivering high-quality, rigorous learning experiences in equal measure to all students from elementary school through higher education. (p. 7)

There has never been a more important time for us to ensure, as an education community, that students receive high-quality science instruction that allows them to grapple with challenges in a first-hand student-centered manner. Teachers’ perceived instruction was largely student-centered before the pandemic and shifted to notably teacher-centered during the pandemic. While teachers’ perceived instruction is shifting back towards student-centered, it has not fully recovered. While we were making progress as a community after the adoption of the Next Generation Science Standards, this study demonstrates that science teachers encountered critical dilemmas when attempting to achieve this vision.

This study corroborates some action areas outlined in the Call to Action. First, science education needs to become a priority, especially in K-5 classrooms (NASEM, 2021, p. 7). Even before the pandemic, teachers in this study expressed challenges with having enough time for science. Now, with an even higher focus on student social emotional needs coupled with focuses on literacy and mathematics, science continues to take a lesser role in school priorities.
Second, teachers need support relieving the stress they are experiencing, which is contributing to existential dilemmas and could cause teachers to leave the field. Madeline Will reported in EducationWeek (2021) that teachers say additional time to plan will help lower their stress, but this is the least likely support to be put into place in schools. Giving teachers the professional development and planning time they need to be their best will ensure our students are receiving the high-quality student-centered science education they deserve.
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Appendix A – Informed Consent

Investigator(s): Jennifer Slavick; David Backer

Project Overview:

Participation in this research project is voluntary and is being done by Jennifer Slavick as part of her Doctoral Dissertation to determine how science teachers and their instruction were impacted because of the effects of COVID-19 on school systems. This study is approved by the West Chester University IRB-FY2022-54. Your participation will take about 7 minutes to complete a survey. There is a minimal risk of becoming uncomfortable with the questions as they will be focused on your teaching experiences during the pandemic. Therefore, there is a risk that you may be uncomfortable recounting your experiences during that time, especially if the pandemic was in any way traumatizing for you. There is also always a risk that the data generated from the study becomes unsecure or that your answers would become identifiable. Finally, there is the risk that you will lose personal time by participating in the study. This research will help the larger scientific education community in that the state of student-centered science before the pandemic and after the pandemic will be clear, allowing those that support the science education community to more clearly target supports.

The research project is being done by Jennifer Slavick as part of her Doctoral Dissertation to determine how science teachers and their instruction were impacted because of the effects of COVID-19 on school systems. If you would like to take part, West Chester University requires that you agree and sign this consent form.

You may ask Jennifer Slavick any questions to help you understand this study. If you don’t want to be a part of this study, it won’t affect any services from the National Science Teaching Association. If you choose to be a part of this study, you have the right to change your mind and stop being a part of the study at any time.

• What is the purpose of this study?
  o To determine how science teachers and their instruction were impacted because of the effects of COVID-19 on school systems.

• If you decide to be a part of this study, you will be asked to do the following:
  o Complete a survey that will take about 7 minutes of your time.
  o Indicate your willingness to participate in an hour-long or less interview.
  o Complete the virtual interview if selected.

• Are there any experimental medical treatments?
  o No

• Is there any risk to me?
  o Possible risks or sources of discomfort include becoming uncomfortable with the questions as they will be focused on your teaching experiences during the pandemic. Therefore, there is a risk that you may be uncomfortable recounting your experiences during that time, especially if the pandemic was in any way traumatizing for you. There is also always a risk that the data generated from the study becomes unsecure or that your answers would become identifiable. Finally, there is the risk that you will lose personal time by participating in the study.
  o If you become upset and wish to speak with someone, you may text the Crisis Textline by typing “Home” to 741741. If you experience discomfort, you have the right to withdraw at any time.

• Is there any benefit to me?
  o There are no direct benefits to participants.
However, the larger scientific education community will benefit in that the state of student-centered science instruction before the pandemic and after the pandemic will be clear, allowing those that support the science education community to more clearly target supports.

- **How will you protect my privacy?**
  - Your records will be private. Only Jennifer Slavick, David Backer, and the IRB will have access to your name and responses.
  - If you participate in the interview, the session will be recorded in order to maintain fidelity to participant responses and allow for more accurate transcription.
  - Your name will not be used in any reports.
  - To further protect you, the survey will collect the grade level taught, the name of the school, and the state where you work in order to gather socioeconomic and cultural data about the student population from a national database. However, you will not be asked for your name or any other identifying information on the survey.
  - Records will be stored via password protected file/computer.
  - Records will be destroyed three years after study completion.

- **Do I get paid to take part in this study?**
  - No

- **Who do I contact in case of research related injury?**
  - For any questions with this study, contact:
    - Primary Investigator: Jennifer Slavick at 267-769-7004 or jen.slavick@gmail.com
    - Faculty Sponsor: David Backer at 203-917-7416 or dbacker@wcupa.edu

- **What will you do with my Identifiable Information/Biospecimens?**
  - Not applicable.

For any questions about your rights in this research study, contact the ORSP at 610-436-3557.

Please sign here to indicate consent.

X
Appendix B – Survey

1. What is the full name of your school district?
2. What is the full name of your school?
3. In what state is your school located?
4. Draw a picture of you as a science teacher at work in the fall of the 2019-2020 school year.

5. Briefly explain, what is the teacher doing and what are the students doing in this picture?
6. What grade level do you teach (circle one)?   K-2   3-5   6-8   9-12
7. Draw a picture of you as a science teacher at work in the fall of the 2020-2021 school year.

8. Briefly explain, what is the teacher doing and what are the students doing in this picture?
9. Draw and upload a drawing or sketch of you as a science teacher at work in the fall of the 2021-2022 school year.

10. Briefly explain, what is the teacher doing and what are the students doing in this picture?
11. If you are willing to participate in a brief interview, please add your email address below.
Appendix C – Modified DASTT Checklist

I. TEACHER
   Activity
   Demonstrating Experiment/Activity/Modeling Using a Document Camera_______
   Lecturing/Giving Directions (teacher talking) ______
   Using Visual Aids (chalkboard, overhead, charts, PowerPoint, Google Slides, etc.) ______
   Position
   Centrally located (head of class) ______
   Erect Posture (not sitting or bending down) ______

II. STUDENTS
   Activity
   Watching and Listening (or so suggested by teacher behavior) ______
   Responding to Teacher/Text Questions ______
   Position
   Seated (or so suggested by classroom furniture) ______

III. ENVIRONMENT
   Inside
   Desks are arranged in rows (more than one row, or students are whole group virtually) ______
   Teacher desk/table is located at the front of the room or teacher is focus of student virtual learning as opposed to breakout rooms ______
   Laboratory organization (equipment on teacher desk or table or teacher is holding materials virtually instead of students holding materials themselves) ______
   Symbols of Teaching (ABC’s, chalkboard, bulletin boards, Google or Virtual Classroom, etc.) ______
   Symbols of Science Knowledge (science equipment, lab instruments, wall charts, textbooks, etc.) ______
Appendix D – Interview Guide

1. Describe your science instruction pre-pandemic. What were you doing? What were students doing?
2. Describe your science instruction in the 2020/2021 school year. What were you doing? What were students doing?
3. In what ways did you try to maintain your pre-pandemic instructional practices?
4. What factors impacted the way you taught in the 2020/2021 school year?
5. Describe your science instructional practices now. What factors contribute to how you are teaching now?