

Pre-Service and Beginning In-Service Teachers' Development of Antiracist and Socially Just STEM Teaching: An Exploration of an Embedded, Extended and Place-Based Model of Teacher Education

by

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Dedication

To my family – for instilling in me the importance and power of education, and for your endless love and support.

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List of Abbreviations

ARSJ – Antiracist and Socially Just

FHS – Fairfield High School

OTL – Opportunities to Learn

STEM – Science, Technology, Engineering and Math

TTS – The Teaching School

Abstract

Calls to strengthen and diversify our nation's STEM workforce outline the need for expansion and improvement of STEM learning opportunities made available to students from minoritized backgrounds. As broader systemic issues of educational inequity disproportionately exclude students from minoritized backgrounds from high-quality STEM learning environments, recruitment and retention of STEM teachers trained in antiracist and socially just (ARSJ) teaching practices is vital. Because traditional STEM teacher education models often separate university from K-12 schooling contexts, university explorations of evidence-based and progressive views of STEM teaching and learning rarely make their way into beginning teachers' repertoires. Furthermore, as pre-service teachers become teachers of record, university supports (e.g., observational feedback, co-planning) often diminish. Thus, learning ARSJ STEM teaching practices requires reimagining traditional teacher education models. Despite such needs, little is known about how pre-service and beginning in-service STEM teachers learn to teach towards ARSJ aims. This begs the question, how might a unique reform model of teacher education serve to achieve this goal?

This dissertation studies teacher learning within a case of a unique reform model of teacher education through extended, embedded, and placed-based supports called The Teaching School (TTS). Throughout the study, I explore four student teachers and beginning in-service STEM teachers' experiences learning ARSJ teaching practices in a pandemic-induced virtual school year. I approach this work through a lens of critical sociocultural learning theory and a framework of seven ARSJ STEM teaching practices.

Throughout the 2020-2021 academic year, I followed two student teachers and two beginning in-service STEM teachers' engagement in and uptake of opportunities to learn ARSJ STEM teaching practices made available through TTS. Making use of design-based ethnographic research methods, I collected over 10 hours of interview data, more than 110 hours of classroom recordings, 139 field notes, and 38 journal entries. I used constant comparative analysis to identify patterns among and across participants and over time.

Across the data, I found distinct differences in participants' commitments to improve on practice and understandings of ARSJ STEM teaching practices, shaping the ways participants engaged in and took up opportunities to learn ARSJ STEM teaching practices. Data related to school culture and mentors suggested that although school community members were dedicated to ARSJ STEM teaching practices, perceptions and approaches to practice varied. Participants' experiences within school culture shaped how they learned about and attempted to enact ARSJ STEM teaching practices, with interactions with mentors who were more aligned with ARSJ STEM teaching practices producing higher and more effective engagement with learning opportunities.

Although all participants displayed commitments to learning ARSJ STEM teaching practices, commitments to improvement on practice, or knowledge of how to improve, varied. Participants who were more successful at learning to integrate ARSJ STEM teaching practices displayed both commitments to ARSJ STEM teaching and improvement on practice. Participants who displayed weaker commitments to improve on practice tended to resist TTS support structures and required additional scaffolding. Across the data, I also found that all participants exhibited desires to draw connections between ARSJ teaching practices and STEM concepts and skills. However, tensions arose when it came to practical enactment.

Together, findings suggest the need for more intentional development of both ARSJ STEM teaching practices and support structures beginning at the pre-service phase. I conclude the study by offering implications for TTS programmatic improvement and the wider teacher education community.

Chapter 1 Introduction

Driven by desires to strengthen and diversify our nation’s workforce in science, technology, engineering, and mathematics (STEM) fields, efforts to attract and retain high quality educators have notably increased over the last ten years, from 2012 to 2022 (Educate to Innovate, 2016; National Research Council, 2012; U.S. Department of Education, 2022). Such calls outline the need for both an increase in the number of qualified STEM teachers and an expansion of the opportunities made available to students from minoritized backgrounds, including girls, students of color, and those attending under-resourced schools. Historically, and presently, broader systemic issues of educational inequity disproportionately exclude students from minoritized backgrounds from high quality STEM learning environments (e.g., Barton, 2003; Barton & Yang, 2000; Carter, 2016; National Research Council, 2012; Windschitl & Calabrese Barton, 2016) and therefore provide fewer opportunities to develop and utilize disciplinary skills that would benefit youth and society at large. Among these issues, recruitment and retention of STEM teachers who are trained to support *all* students in developing disciplinary identities and skills is of utmost importance, particularly in under-resourced areas. Furthermore, recent trends in our nation’s teaching force indicate that approximately 80% of teachers are White¹ and 70% of teachers are female (U.S. Department of Education, 2020),

¹ I choose to capitalize “White” throughout this dissertation to call attention to the distinct cultural markers and material benefits that accompany Whiteness. Choosing not to capitalize White “runs the risk of reinforcing the dangerous myth that White people in America do not have a racial identity” (Ewing, 2020), which has the potential to reify Whiteness as acultural or the norm. Furthermore, APA guidelines indicate that “Black” and “White” should be used in place of “black” and “white” when referencing racial or ethnic groups (American Psychological Association, 2023). In response to and in support of such guidelines, the Center for the Study of Social Policy (2020) released the following statement: “To not name ‘White’ as a race is, in fact, an anti-Black act which frames Whiteness as both neutral and the standard [and] allows White people to sit out of conversations about race.”

representing only a segment of an increasingly diverse K-12 student population. Further still, most teacher educators are White and female (Ladson-Billings, 2005), creating a potential cycle of implicit or explicit projections of a culture of power (Delpit, 1988) onto pre-service teachers and, in turn, K-12 students. When not approached through a critical lens, traditional models of teacher education, I argue, run the risk of reproducing inequities and further excluding historically marginalized youth from high-quality STEM learning environments and STEM career pathways. Thus, this study – motivated by the desire to improve STEM teacher education towards antiracist and socially just (ARSJ) aims – explores how a unique reform model of educator preparation might serve to achieve that goal.

Engaging in ARSJ STEM teaching practice, I argue, necessitates a reimagining of the teacher education space as one of transformation (Picower, 2021). As will be exemplified in the subsequent chapter, preparing teachers for ARSJ STEM teaching practice can be seen in various iterations across the literature, few of which encompass both ARSJ and STEM foci. Although many studies attend to preparing teachers for *socially just* STEM teaching (e.g., Bianchini & Cavazos, 2007; Furman et al., 2012; Mensah, 2011), few attend to preparing teachers for *antiracist* teaching (e.g., Goldin et al., 2021; Khasnabis et al., 2019), and even fewer were focused on preparing teachers for *antiracist STEM* teaching. Thus, this dissertation aims to fill an important gap in the literature to further understand how we might better prepare pre-service and beginning in-service STEM educators to teach in antiracist and socially just ways.

Specifically, the qualitative study I report here examines the perceptions and teaching trajectories of pre-service and beginning in-service STEM teachers learning to teach in an embedded, extended, and place-based model of teacher education known as The Teaching School (TTS). Focusing on the development of ARSJ STEM teaching, I explore the

opportunities to learn made available to participants, as well as how they took up such opportunities in their perceptions of teaching philosophy and practice. The research questions guiding my study are:

1. What are the opportunities to learn ARSJ STEM teaching practices made available through The Teaching School model?
 - a. How do participants take up such opportunities to learn?
2. How do participants talk about their perceptions of ARSJ STEM teaching, as it relates to their teaching practice and development?
3. How does The Teaching School model support and constrain prospective and novice teacher development around ARSJ STEM teaching practices?

In developing these questions, I draw on my expertise as a teacher educator and researcher, as well as my experience as a former high school science teacher attempting to teach in antiracist and socially just ways. In the section that follows, I provide a brief glimpse into my experience as a novice teacher to further foreground my motivation for this work, as well as the personal lens with which I approached design and analysis. Then, I turn to framing the problem at the core of my study.

Personal Experience as a Novice Teacher

“Education is the most powerful weapon which you can use to change the world.”

The year is 2014 and the above quote from Nelson Mandela sits in a wooden frame adorning my desk in the back corner of the room. Above it, colorful posters of the periodic table and the rock cycle flank a whiteboard indicating the day’s agenda and warm-up question. Today, students are going to learn about half-life as a method by which to determine the absolute age of a rock. At least, that is my hope. You see, I am a first-year earth science teacher at a charter

school in the downtown area of a large midwestern city, and my days do not always go according to plan. Although I fully believe education is a powerful tool in building a more just society, and it is why I am here, I do not yet know how to utilize this tool in my teaching practice. This is a difficult realization, as I felt as though I was set up for success in many ways. The year prior, I earned a master's degree in educational studies, a teaching certificate, and had completed a year of student teaching in the city's public school district. However, as a first-year teacher, and a White woman teaching a majority Black student population, I still had – and have – a lot to learn.

Deep in survival mode, I found it difficult to create and adapt lesson plans that were project-based and engaging, met content standards, and connected deeply with students' lived experiences as well as with larger themes of justice. Later in the year, students will refer to me as “light-skinned,” not White, which I accept as one of the highest compliments they can offer. And although I succeeded in building meaningful relationships across difference, I had a long way to go in terms of designing the community and justice-centered project-based units with which I hoped to engage students. My goal was for students to not only feel valued in my class, but also to gain access to conventional scientific knowledge in a way that provided the opportunity for critique and transformation. Thus, my inability to engage *all* students in this type of science learning and prepare for future STEM workspaces fell short of providing a truly socially just and antiracist educational experience. Nevertheless, I was lucky to be at a school that explicitly touted education for liberation and sought to hire educators dedicated to celebrating Black excellence. The school clearly had goals of antiracism and social justice. However, I did not have consistent embedded supports to help improve my practice as a novice teacher, such as individualized coaching, co-planning, and sustained opportunities to reflect on my power and privilege and how these manifested in my curricular and instructional decisions. Driven by the

dilemmas I experienced, I now study how we might enhance and improve teacher education and early-career teacher supports towards ARSJ STEM teaching practice. In my current role as a researcher and teacher educator, and throughout this dissertation, I wish to explore how such supports may contribute to building stronger educator preparation programs to better serve the needs of children towards a more just society.

Framing the Problem

Given a decline in teacher education enrollment and increased teacher attrition in recent years, there is a critical need to both develop and retain high quality educators, particularly in areas with our nation's most vulnerable youth. In the state of Michigan, recent trends in teacher education enrollment indicate a decrease by about half from 18,463 prospective teachers in the 2013-2014 academic year to 9,760 in 2019-2020 (Michigan Department of Education, 2022). This troubling trend is coupled with the realities of STEM learning spaces as exclusionary sites for far too many students of color (e.g., Calabrese Barton, 2003; National Research Council, 2012; Windschitl & Calabrese Barton, 2016). Furthermore, teachers are more likely to leave schools in urban districts and schools with students from minoritized backgrounds, and teachers of science and math are more likely to "migrate," or change schools or districts than teachers in other disciplines (Ingersoll, 2001). On the contrary, research demonstrates that teachers who are more effective are more likely to stay, even in under-resourced areas (Ronfeldt et al., 2013). Thus, we are faced with a challenge of not only populating classrooms but doing so with individuals who are prepared and supported to provide high quality ARSJ STEM learning opportunities for all students. How are teacher educators and certificate-granting institutions, such as universities, heeding this call and not only recruiting, but also continuing to support novice teachers to be successful? I explore questions such as this throughout this dissertation,

and I argue there is a need to reimagine what STEM teacher education might look like, specifically for contexts with youth from minoritized backgrounds. Put simply, too many novice teachers are ill-prepared to provide youth with the STEM instruction necessary to realize a socially just and antiracist educational landscape.

What are some of the reasons for this dire situation? One reason is the nature of preparation most teachers currently experience. Traditionally, teacher education takes place in two seemingly disparate settings: the university and the K-12 classroom (Feiman-Nemser & Buchman, 1985). Across these settings, the university often presents progressive, evidence-based views of education, while K-12 classroom settings focus more heavily on “traditional teaching practices and curriculum coverage as a primary concern” (Thompson et al., 2013, p. 576). Additionally, K-12 classroom spaces often espouse neoliberal visions of STEM education where access to opportunity and application of knowledge is viewed as the responsibility of K-12 students, rather than systemic or structural factors (e.g., Calabrese Barton & Yang, 2000; Carter, 2016). Bain and Moje (2012) describe this separation of contexts as a sort of “continental drift” (p.62), where pre-service teachers are left to navigate sometimes opposing worlds largely on their own. This contextual separation, as well as the pre-service teacher’s place in it, is depicted in Figure 1-1 (below).

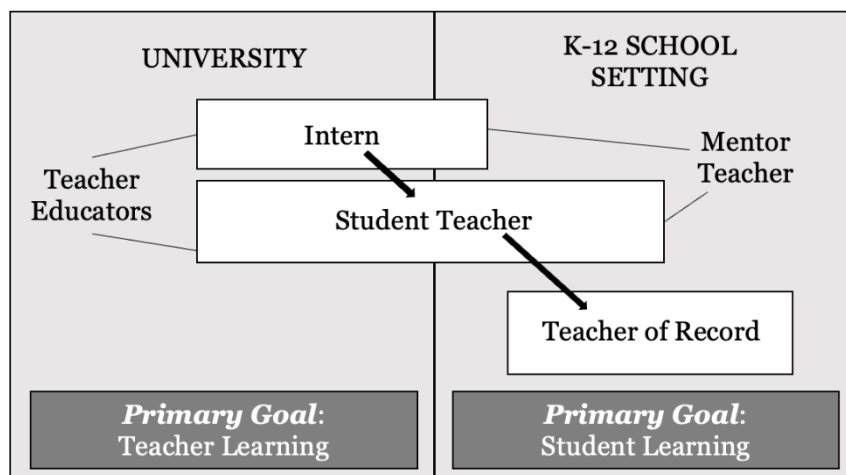


Figure 1-1. Traditional teacher education model

Although details of specific educator preparation programs across the country vary, a typical pre-service teacher trajectory consists of an internship, followed by student teaching, ultimately resulting in a position as a teacher of record. Beginning as an intern, the pre-service teacher typically spends most of their time in university settings taking coursework and relatively small amounts of time in K-12 classrooms, as indicated by the relative overlap across the university and K-12 school setting in Figure 1-1 (above). As an example, interns in a school of education at a large research university in the midwestern United States spend two half days in a mentor teacher’s classroom during two consecutive internship semesters. Next, pre-service teachers move into their semester of student teaching. During the student teaching semester, student teachers spend all day, every day in the classroom, gradually increasing the time they spend as the lead teacher while continuing to engage in coursework at the university. In the student teaching semester, student teachers’ relationships with their mentor teachers are primary aspects of their learning, with a single seminar to deconstruct their practice offered once weekly. In both intern and student teacher experiences, the university and K-12 classroom settings do not necessarily overlap, nor do student teachers share K-12 classroom sites with others in their

cohort. Thus, when interns and student teachers engage in university coursework discussions, the K-12 contexts within which their ideas are rooted are dissimilar from that of their peers, reducing the possibility for meaningful discussions about problems of practice and potential supports. Finally, as a student teacher transitions into a fully certified teacher of record, the teacher is firmly set in the K-12 classroom setting, with little to no contact with the university supports they experienced as an intern or student teacher, and with any supports from the school or district dependent on a given district's or school leader's commitments to supporting new teachers.

Not only do pre-service teachers find themselves navigating sometimes opposing contexts, but the primary goals set out by each institution also are not necessarily shared across settings: universities are primarily concerned with and responsible for teacher learning while K-12 school settings are primarily concerned with and responsible for student learning. As certificate-granting institutions, the university setting is primarily concerned with teacher learning. This is unsurprising, as teachers who leave an educator preparation program must possess certain pedagogical skills and attain a certain degree of efficacy as based on university and state-wide evaluative measures. Relatedly, mentor teachers in K-12 school settings are also working to support their students in developing disciplinary skills and attaining a certain level of performance on evaluative measures. Although I might argue that teacher educators are, or should be, equally concerned with student learning as they are teacher learning, our institutions of higher education are not fully equipped to focus on children's learning and are not typically included in K-12 school decision-making. However, without shared goals of both student and teacher learning across institutional settings, teacher education programs and placement sites run the risk of placing pre-service teachers in situations where they are simply "trying things on" with K-12 students, causing harm both knowingly and inadvertently.

In response to such contextual and philosophical divides, I focus this dissertation on a case of a unique reform model of educator preparation called The Teaching School (TTS). Within this model, teacher education supports are embedded, extended, and place based. TTS was designed to support educators from teacher candidacy through the first three years as a teacher of record in partnership between a school situated in a large urban school district and a large research university in the midwestern United States. Within TTS, stakeholders share joint goals of student and teacher learning through antiracist and socially just teaching practice. In the chapters that follow, I explore literature related to the design and implementation of TTS and provide further contextual information. In the remainder of this chapter, I turn to a discussion of my research questions and an overview of the study.

Research Questions and Overview of Study

My study was designed to examine closely how TTS model – still in its infancy – is working, with a focus on the affordances and constraints of conducting teacher education as extended, embedded, and place-based. Given my interest in preparing STEM teachers to integrate ARSJ practice into their STEM teaching, I zoom in on the opportunities for those teachers to learn and examine how they take up those opportunities. Although this is not a study of STEM teaching, per se, I did observe teaching as fodder for understanding how TTS teachers are learning to become ARSJ STEM teachers. It is important to note that exploring this idea does not preclude all the useful strategies and practices traditional models of teacher education have to offer – many educators, including myself, have benefited from the research-based coursework and accompanying clinical experiences offered in many traditional settings. However, traditional models simply may not afford enough time for teacher candidates to reexamine their own positionality and bias, as well as consider STEM teaching as a cultural process where cultural

and discursive norms have historically benefited White and middle-class communities (Emdin, 2011; Lemke, 1990; Schleppegrell, 2007), further upholding systems of White supremacy. Discounting the time and types of support needed for incoming STEM teachers to examine how they might uphold a status quo of STEM participatory and discursive conventions does little to transform STEM educational experiences for youth. Such participatory and discursive conventions often favor White, male, middle-class values (Moje et al., 2004), which implicitly or explicitly favor students whose out-of-school cultural practices most align with those of in-school cultural practices (Nasir et al., 2014). I hypothesize that breaking this cycle, and better supporting youth from minoritized backgrounds in STEM learning spaces, requires extended educator supports aimed at developing ARSJ teaching practice. To those ends, I ask, what does it mean to support teachers from pre-service through beginning in-service years within and for the context they plan to teach? Further, what does it mean to support STEM teachers within a space committed to dual goals of teacher *and* student learning with underlying foundational objectives of antiracism and social justice? Through this dissertation, I seek to contribute to this knowledge base. Specifically, I asked the following questions:

4. What are the opportunities to learn ARSJ STEM teaching practices made available through The Teaching School model?
 - a. How do participants take up such opportunities to learn?
5. How do participants talk about their perceptions of ARSJ STEM teaching, as it relates to their teaching practice and development?
6. How does The Teaching School model support and constrain prospective and novice teacher development around ARSJ STEM teaching practices?

In this qualitative study, I studied the TTS model by examining the perspectives of two mathematics student teachers, two early-career science and engineering teachers, and two mentor teachers teaching mathematics and science, who took part in TTS' early year, which was conducted wholly online due to the COVID-19 pandemic. I examined participants' engagement with opportunities to learn ARSJ STEM teaching practice, some of which I co-designed and facilitated. Throughout the year, I attended novice teachers' classrooms via an online schooling platform and facilitated subsequent debrief and coaching sessions. Interactions with student teachers were a bit more limited given the virtual nature of instruction due to the pandemic, though I was able to attend student teaching seminars and interview student teachers at multiple points throughout the year. In examining participants' opportunities to learn ARSJ STEM teaching practice, I also examined the ways in which such opportunities made their way into their perceptions of teaching. Lastly, I was interested in the affordances and constraints of TTS model, particularly in supporting participants' development of ARSJ STEM teaching practice. I offer more details on the design and methods of the study in Chapter 3.

Organization of the Dissertation

Through the following chapters I explore how these prospective and beginning STEM teachers made sense of opportunities to learn ARSJ STEM teaching practice within TTS model. In Chapter 2, I present a review of relevant research literature, as well as a conceptual framework for the study. As noted previously, this is not a study of ARSJ STEM teaching; however, to examine the opportunities new teachers have to learn ARSJ STEM teaching practices, I needed to review the relevant literature on said practices to inform the design of my data collection instruments and observational foci. As a result of that review, I also present a conceptual model of ARSJ STEM teaching practice. Additionally, I explore how previous models of teacher

education have afforded or constrained the development of ARSJ STEM pedagogies and explore how TTS model might be different. Chapter 3 focuses on research design and methods. Because I used ethnographic design-based methods in the execution and analysis of this work, this chapter gives specific attention to the study context and participants. In chapters 4 through 6 I present my findings, including the ways in which varying degrees of alignment across participants and school community members both afforded and constrained the development of ARSJ STEM teaching (chapter 4), the ways in which participants' varying levels of reflexivity and connections to agency shaped their engagement with learning opportunities (chapter 5), and how perceived connections between STEM and ARSJ teaching both widened and narrowed participants' scope of instructional possibilities (chapter 6). Chapter 7 discusses these ideas in relation to each other, and I bring the dissertation to a close by offering important implications for the field of STEM teacher education, particularly for STEM teacher educators interested in pursuing ARSJ STEM teaching practices.

Chapter 2 Literature and Conceptual Framing

This study aims to explore teacher learning within a case of a unique reform model of educator preparation – The Teaching School (TTS) – which makes use of embedded, extended, and place-based supports in preparing pre-service and beginning in-service STEM teachers to teach in ARSJ ways. As such, I draw on various theoretical and empirical research to frame the study and provide warrant for the research questions, which focus on understanding participants’ experiences with opportunities to learn ARSJ STEM teaching practices within TTS model. In the review, I include a) literature on attempts to develop ARSJ STEM teaching with both pre-service and in-service teachers, b) literature on various teacher education models that have been explored over time, and c) literature on models used in other types of professional education, with an emphasis on medical education approaches. I examine these three fields of literature to explicate the connections between the types of supports and structures that serve to support pre-service and beginning in-service STEM teachers in developing ARSJ teaching practices and to ground the design of my study.

I begin this chapter by presenting my conceptual framework on learning, teaching, and learning to teach, which draws on critical sociocultural perspectives and communities of practice. Such perspectives support my research design, the data collection methods I chose, and the lens through which I analyzed data and considered implications for the work. Then, I turn to a definition of ARSJ teaching practices, drawing on a breadth of literature across multiple disciplines before delving into STEM-specific ARSJ teaching practices. Next, I explore empirical literature related to pre-service and beginning in-service STEM teachers’ development

of ARSJ practices. Then, I present the current state of teacher education literature related to various models of teacher education, such as lab schools, professional development schools, and residencies. I explore this literature because it is important to understand where TTS lies regarding previous teacher education reform over time, as well as how the model perhaps draws on, yet distances itself from, such teacher education efforts. Following the discussion of teacher education reform models, I present research on other forms of clinical education to explore what they offer as models for the work.

Conceptual Frame

Introducing Sociocultural Theories of Learning

Throughout this dissertation I draw on sociocultural theories of learning to focus my conceptual and analytic lens. I use the term sociocultural theories to describe a collective body of literature that draws on Vygotsky's theorization of learning and development through social and cultural processes (e.g., Cole, 1977; Esmonde & Booker, 2016; Gutiérrez & Rogoff, 2003; Moje & Lewis, 2007; Nasir et al., 2014; Nasir & Hand, 2006; Wertsch & Tulviste, 1992), and expands upon previous theories and understandings of individual cognitive development (e.g., Piaget, 1952, 1970). As described by Cole (1977), sociocultural theory aims to connect our understanding of cognition and the surrounding social context and culture. He points out that according to Vygotsky, "every complex psychological function...first emerges as a social function" (p.x). Similarly, Wertsch and Tulviste (1992) describe Vygotsky's approach to learning and development as "sociocultural, in that it incorporates socially evolved and socially organized tools" (p.551). In his own words, Vygotsky (1978) asserts that "human learning presupposes a specific social nature and a process by which children grow into the intellectual life of those around them (p. 88). Thus, learning and development do not occur in a vacuum.

Rather, learning occurs through social interactions that also carry with them a sense of historicity in that “any learning a child encounters in school always has a previous history” (Vygotsky, 1978, p.84). Applying this to the world of teacher education and the development of ARSJ STEM teaching practice, it is vital to analyze teacher learning through the lens of previous experience and interactions within social and cultural processes across TTS model.

In studying teacher learning within TTS model, I assert that learning and development are inherently social (Vygotsky, 1978) and cultural processes (Nasir et al., 2014). As pre-service and beginning in-service teachers enter the K-12 school context their interactions with peers and mentors, mediated by cultural tools and artifacts, support the development of orientations to practice. As new teachers “engag[e] in activities stemming from observing and otherwise participating in cultural practices” (Gutierrez & Rogoff, 2003, p.22), they begin to develop a host of resources to draw from in building relationships, interacting with the school community, and enacting instruction. This view of learning “requires a focus on how individuals participate in particular activities, and how they draw on artifacts, tools, and social others to solve local problems” (Nasir & Hand, 2006, p.450). Thus, learning how to engage in ARSJ STEM teaching practice becomes more than simply “doing” or enacting instruction, but also how pre-service and beginning in-service teachers approach such practice and begin to situate themselves and obtain membership within a community of practitioners (Lave & Wenger, 1991; Moje & Lewis, 2007; Wenger, 1998).

Critical Sociocultural Theories of Learning

Exploring how participants learn ARSJ STEM teaching practices, with a focus on what dimensions of TTS model seem to open or constrain learning possibilities, necessitates a critical view of sociocultural theories of learning. Throughout the process of learning to teach STEM in

ARSJ ways, it is important to consider the cultural nature of STEM disciplines and how power operates within them. Although the sociocultural theories described above attend to engagement with others in learning to teach, they fall short of incorporating additional layers of cultural context and power (Esmonde & Booker, 2016; Moje & Lewis, 2007). Taking a critical view means examining how one learns to teach STEM while navigating a traditional view of the disciplines as acultural and objective (e.g., Harding, 1991, 2015), and a reimagined view that takes cultural context and power into consideration. For youth, gaining entry into a community of recognized STEM doers and thinkers is complicated by issues of race, class, and gender that permeate STEM disciplinary learning and career environments. Thus, supporting prospective and beginning STEM teachers in learning to teach in ARSJ ways necessitates obtaining membership into a community of practitioners that take up such ideas in their ongoing professional development and work to support K-12 students' STEM concept and skill learning in transformative ways.

Communities of Practice

A focus on learning as participation within historical and social contexts lends itself to thinking about “communities of practice” (Lave & Wenger, 1991; Lave, 1991; Wenger, 1998). Within a community of practice, “collective learning results in practices that reflect both the pursuit of our enterprises and the attending social relations” and “are created over time by the sustained pursuit of a shared enterprise” (Wenger, 1998, p.45). In the case of TTS model, the *intended* shared enterprise is the development of ARSJ STEM teaching practices. I highlight the term *intended* because although ARSJ STEM teaching practice is a stated goal of the program and a central tenet of the model itself, analysis may show that not all participants shared these same goals, or the same perceptions of said enterprise. Participants gain entry into a community

of practice through what Lave (1991) refers to as *legitimate peripheral participation* wherein “old timers” and “newcomers” engage in joint activity and “newcomers...participate peripherally in ongoing activities of the community” (p.68). Intergenerational structures within TTS model offers various opportunities for participants to engage in activities of the community as both “old timers” and “newcomers.” For example, novice teachers are positioned as newcomers in their interactions with mentor teachers and teacher educators, yet they are considered old timers when it comes to interactions with interns, student teachers, or novices earlier in their teaching career. These near-peer interactions situate participants in various opportunities to learn and build communities of practice around ARSJ STEM teaching. Throughout this study, I explore how participants engaged in such opportunities to learn and how the model itself affords or constrains entry into a community of ARSJ STEM teaching practitioners.

Defining and Delimiting Antiracist and Socially Just STEM Teaching Practices

To explore participants’ learning of ARSJ STEM teaching practices within TTS model, it is important to understand the practices themselves. As such, this section delves into ARSJ STEM teaching practices and provides a framework of seven practices explicated through literature on ARSJ STEM teaching in practice.

Developing ARSJ STEM teaching practice requires an examination of the seemingly objective nature of STEM disciplines (Gholson & Wilkes, 2017; Harding, 1991; Martin et al., 2010). Although these disciplines have historically been presented as acultural (Bang & Medin, 2010; Lemke, 1990) and static (Grossman & Stodolsky, 1995; Stodolsky & Grossman, 1995), “science and their philosophies have never been value free” (Harding, 2015, p. 2). Issues such as environmental and scientific racism (Brown & Mutegi, 2010; Bullard, 2018) and medical apartheid (Washington, 2006) plague the scientific community. Yet, most STEM schooling

experiences present these fields as “culturally neutral and invented by White males” (Crockett, 2008, p. 2), which appears to be an oxymoron. How can something be both culturally neutral and invented by a set of individuals who both shape and are shaped by the dominant culture of power (Delpit, 1988)? Such framing suggests that White culture is often considered synonymous with no culture at all, further cloaking White cultural influence on STEM fields in false objectivity. Furthermore, suggesting an “acultural” perspective continues to foster an educational environment where White discursive and participation norms become ever more pervasive (Emdin, 2011; Moje et al., 2004; Schleppegrell, 2007). Over time, such discursive and participation norms become reified as they are rarely questioned or interrogated. Ignoring STEM “historical, political, and sociocultural forces all too often work in support of the status quo” (Carlone, 2012, p. 24), which far too often finds students of color at a disadvantage to their White counterparts (e.g., Chambers, 2009).

In defining ARSJ STEM teaching practices I draw on multiple perspectives on transformative pedagogies, namely culturally relevant pedagogies (Ladson-Billings, 1994, 1995), culturally sustaining pedagogies (Paris, 2012; Paris & Alim, 2017), critical pedagogies (Freire, 1970, 1998, 2000), and justice-centered science pedagogy (Morales-Doyle, 2017). As laid out by Ladson-Billings (1995), culturally relevant pedagogies (CRP) require the realization of three criteria: “a) students must experience academic success, b) students must develop and/or maintain cultural competence, and c) students must develop a critical consciousness through which they challenge the status quo of the current social order” (p.160). Ladson-Billings’ foundational work draws on Freire’s (1970) notion that it is necessary for students to develop a sense of critical consciousness, which he refers to as *conscientizado*. Freire and others (e.g., DeNicolò et al., 2017) assert that the development of critical consciousness is essential in

disrupting systemic inequities for minoritized youth. Without the element of uncovering and questioning the status quo, there is no reimagining or rebuilding a more equitable and just educational landscape for youth. Reimagining a more equitable and just educational landscape requires a rejection of the passive transfer of knowledge, or a banking model, and instead “to create the possibilities for the production or construction of knowledge” (Freire, 1968, p. 30). Such production or construction of knowledge must also draw and build upon on students’ diverse and rich cultural histories. Paris and Alim (2017) extend Ladson-Billings’ (1994, 1995) ideas to “reimagine schools as sites where diverse, heterogeneous practices are not only valued but *sustained*” (p.3, emphasis in original) in their theorization of culturally sustaining pedagogies (CSP). As the authors assert, CSP was developed as “paradigm shift” (p.158) in response to the need to revisit CRP, which Ladson-Billings (2014) has acknowledged as picking up where she left off: “culturally sustaining pedagogy uses culturally relevant pedagogy as a place where the beat drops” (p.76, as cited in Paris & Alim, 2017, p.5). The use of the term *sustaining* works to emphasize Ladson-Billings’ (1995) second criterion to develop and/or *maintain* cultural competence and provides the research community with “a term that supports the value of our multiethnic and multilingual present and future” (Paris, 2012, p.93).

Building off the pedagogies above, justice-centered science pedagogy (Morales-Doyle, 2017) centers the work of social justice in positioning youth as “transformative intellectuals” (p.1037) in their science learning experiences. Justice-centered science asserts that issues of equity are intricately tied to issues of social justice in schools (Barton, 2003; Duncan-Andrade & Morrell, 2008; Noguera, 1996) and aims to make such issues explicit in designing and carrying out transformative science instruction. Furthermore, I draw on justice-centered science pedagogy in developing a conception of “antiracist” teaching as it centers race as a vital component

(Blakeney, 2005). As Morales-Doyle (2017) asserts, “developing an analysis of white² supremacy is important because science is often positioned as objective” (p.1037). Uncovering the ways in which race permeates all aspects of STEM educational experiences begins to shed light on the often-implicit messages about race and *who does STEM* (Donovan, 2014; Wade, 2015). Justice-centered science also makes clear that rigorous science content learning is central to gaining access to systems of traditional Western science (Mutegi, 2011), which is often viewed as separate, or left out of critical pedagogies. However, sole focus on Western science negates more expansive epistemic views and falls short of transforming the STEM landscape for youth (Bang et al., 2012; Bang & Medin, 2010; Bang & Vossoughi, 2016). Thus, indigenous and non-Western ways of knowing, doing, and being in science (e.g., Harding, 2011; Smith et al., 2018) should also be considered in developing transformative STEM learning experiences for youth.

Although ARSJ STEM teaching draws heavily on the pedagogical traditions described above, I make several distinctions. First, I assert that antiracism must be made more explicit in the naming of the practice. Just as CSP reimagined and expanded upon CRP (Paris & Alim, 2017), I too expound upon justice-centered practice by highlighting “antiracism” and elevating the rightful centering of race. Highlighting antiracism allows for “critique [of] the positivist assumptions of knowledge, of an objective and universal truth, which fails to acknowledge the embedded Eurocentrism and male privilege” (Kishimoto, 2018, p.541), which is particularly useful in relation to STEM fields. Secondly, I assert that the work of ARSJ STEM teaching must be focused on not only issues of social justice, but *socially just* teaching practice (Moje, 2007). Moje (2007) differentiates between socially just and social justice in that socially just instruction

² Direct quotes from sources make use of the author’s original use of “white” or “White.”

“not only provides opportunities for youth to learn with proficiency the established knowledge of a given field or disciplines but that also encourages youth to question, critique, and produce new knowledge within the disciplines” (p.34). In this sense, socially just STEM teaching does more than highlight social justice issues within curricula, which is a critical component – it permeates every aspect of the work. Socially just STEM teaching empowers students to take ownership over their learning to transform knowledge and communities (Tan et al., 2012). Similarly, Herrenkohl & Mertl (2010) argue that for students “to become engaged participants who in turn change the intellectual, social, and cultural landscape as a result of their work” (p.2), mere access to knowledge and skill is not enough. Rather, socially just teaching works to “develop students who can both understand and critique the existing social order” (Ladson-Billings, 1995, p.474) towards a more equitable and just future. Lastly, I make an important distinction by providing a framework within which to identify ARSJ STEM teaching in practice. In the pages that follow, I present this framework through seven core ARSJ teaching practices.

The framework presented on the following page (Figure 2-1) highlights ARSJ core teaching practices with specific attention to STEM disciplinary teaching and learning. As depicted in Figure 2-1, ARSJ teaching practices are first presented as non-disciplinary specific in that all ARSJ teaching practices could be applied to a myriad of disciplines. For the purposes of this dissertation, however, I conceptualize ARSJ *STEM* teaching practices and provide specific examples of each element of ARSJ teaching in practice in relation to developing disciplinary STEM concepts and skills with youth. Following the presentation of the framework, I further explicate each ARSJ STEM teaching practice and provide examples of practical enactment.

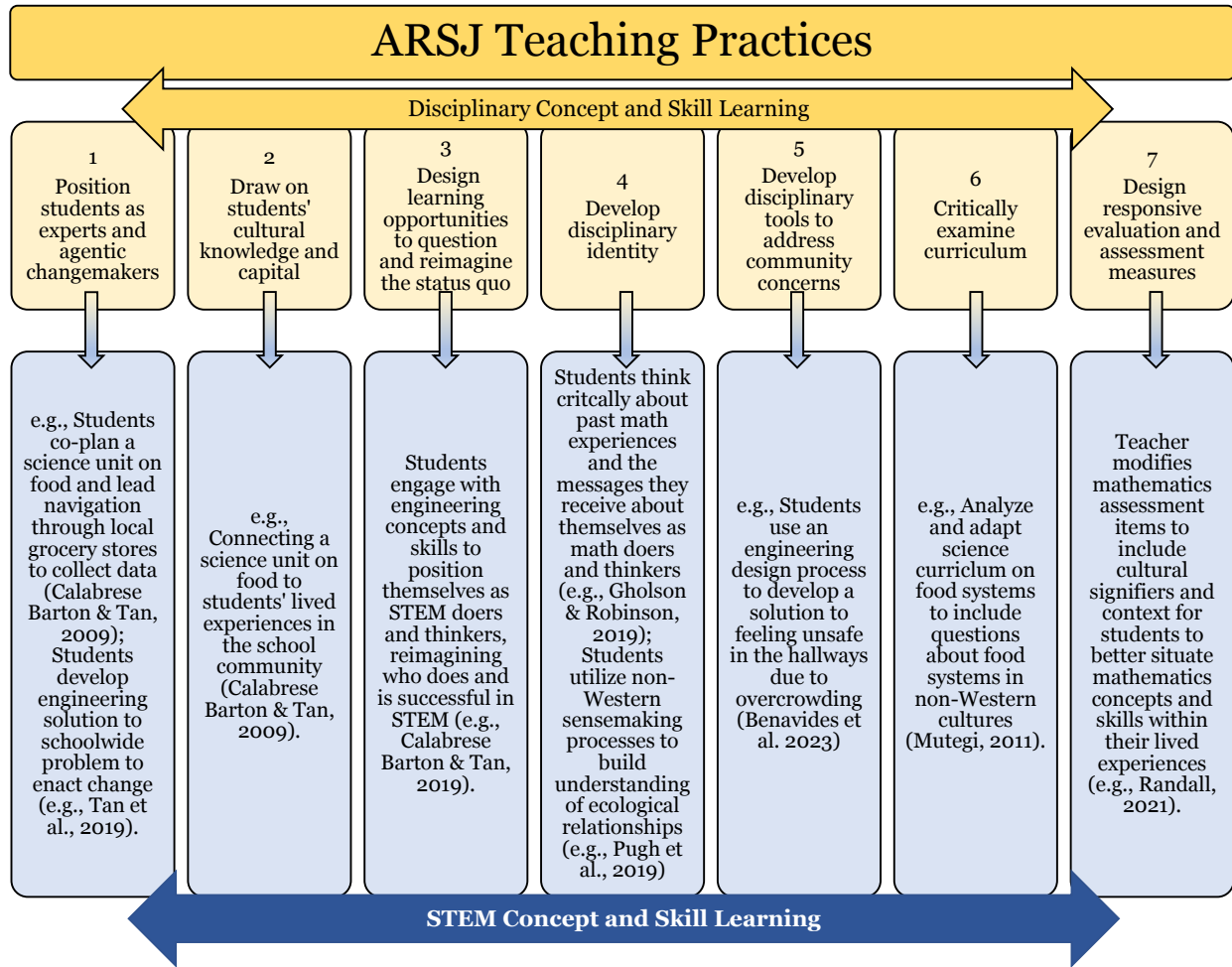


Figure 2-1 ARSJ STEM Teaching Practices

As shown in Figure 2-1 (above), I conceptualize ARSJ teaching into seven distinct, yet related, practices. The purpose of the numbers is to ease in identification and explanation within this dissertation, as well as perhaps when referencing with pre-service and beginning in-service teachers, which I will expound upon in the conclusions and implications chapter. The numbers do not, however, indicate a spectrum or hierarchy of practices. For example, the numbers do not imply that one must master or complete practice 1 (position students as agentic experts and changemakers) before moving on to practice 6 (critically examine curriculum). On the contrary, it may be the case that educators find it useful to start by examining curricular materials before finding ways to position students as experts in classroom activities. It could also be the case that

such practices are happening simultaneously. I further address the interconnected nature of the practices at the end of this section, after I have explicated each practice and provided practical examples.

Additionally, as the bi-directional arrows in Figure 2-1 indicate, STEM disciplinary concept and skill learning is the throughline and lens through which all ARSJ STEM teaching practices are considered. As such, supporting students' sensemaking through STEM concept and skill learning is at the foundation of each ARSJ STEM teaching practice. If ARSJ STEM teaching practices are not rooted in meaningful STEM learning, then STEM teaching runs the risk of reifying the status quo wherein students from marginalized backgrounds are continuously excluded from STEM learning opportunities and career pathways. In reference to science learning towards social transformation, Mutegi (2011, p.310) asserts "mastery of content is essential." However, content learning alone is not enough. Although STEM concept and skill learning widens opportunities for students to use their knowledge in myriad ways, it does not ensure that such knowledge will be used towards the transformation of schooling and society towards ARSJ aims. Furthermore, myopic focus on concept and skill learning with little to no adaptation or attention to cultural context serves only a segment of the student population, most commonly those who are already aligned with the traditionally Eurocentric nature of STEM schooling environments. Thus, a sole focus on STEM concepts and skills falls short of transformative learning experiences towards ARSJ aims. In placing STEM concept and skill learning as the foundation for ARSJ STEM teaching I attempt to bridge a common divide between STEM content and elements of ARSJ teaching and learning. Contrary to commonly held beliefs about STEM as objective, STEM fields are laden with cultural norms and discourse practices that often reflect that of White, male, middle-class cultural practices, though they are

perceived to be separated from such influence perhaps more so than any other discipline. As STEM teachers enter the pre-service and early career in-service phases of their careers, such an attempt to connect STEM concept and skill learning with ideas about what it means to teach in ARSJ ways is critical. Put simply, separating STEM concepts and skills from ARSJ teaching negates the potential for meaningful and transformative learning outcomes for youth. As will be expounded upon further, each ARSJ STEM teaching practice must be intertwined with STEM concept and skill learning for true ARSJ teaching to occur. In the following pages, I explicate each of the ARSJ STEM teaching practices and provide practical examples.

(1) Teacher positions students as experts in their culture and agentic changemakers when facilitating STEM learning opportunities.

Learning STEM concepts and skills is made more accessible to students when the teacher positions them as experts in their culture and agentic changemakers, particularly for students from minoritized backgrounds who are not always positioned as such in STEM learning spaces (e.g., González et al., 2007; Morales-Doyle, 2017). To enact this practice, the teacher must commit to both learning about students' interests, identities, and communities and shifting the traditional power dynamic in the classroom from teacher as sole holder of knowledge to that of students as meaningful and critical contributors of knowledge. As an example, Calabrese Barton and Tan (2009) explored the potential for increased student participation and mastery of science content through a 6th grade science unit exploring healthy food options co-planned by the authors, teacher, and students in a school with a predominantly Latinx student population. As part of the unit, the class visited a local grocery store often frequented by students to analyze food choices and explore healthy options. In this environment, students were experts in navigating aisles, conversing with store personnel, and locating healthy food options. The

authors found that throughout the unit students were encouraged to use everyday discourse and exhibited higher levels of content understanding and achievement, as indicated by grading data at the end of the unit. Interestingly, when implementing more traditional teacher-centric instruction at certain points throughout the unit, such as small lectures, students reverted to using discourse more reminiscent of school science and participation decreased. Positioning students as experts not only improved evaluation measures, but it also allowed for a shift in power from teacher as sole holder of knowledge to that of knowledge facilitator. As described by the authors:

[The teacher] himself changed from that of ‘science expert authority figure’ to ‘facilitator’ of a round table discussion where each member, students and teacher alike, came with valuable resources to add to the dialogue...In these lessons, [the teacher] ‘shared’ his authority as the resident expert with the students (p.41).

Through this shift in classroom power dynamics and centering students’ cultural expertise, students participated in science learning opportunities in new, different, and more robust ways.

In addition to sharing authority, teachers can position students as experts in STEM learning spaces through the learning opportunities they design for youth. As an example, an engineering unit designed for sixth grade students allowed for engagement with Next Generation Science Standards (NRC, 2012) of defining problems and designing solutions, as well as a chance for students to see themselves as agents of change in the school community (Tan et al., 2022). Within the unit, students collected interview and survey data from parents and students and found that students were unhappy and school morale was generally low. Upon defining this problem, students designed a solution called “The Helping Hands” board to be displayed in the school hallway. According to the authors:

The interactive poster was beautifully decorated, filled with pictures of happy animals, hearts, and diamonds, with a set of ‘helping hands’ reaching out...[and] lights-up when an attached hand-crank generator is turned. The instructions read: ‘Use the board when you are feeling down (have a time out) and want to be picked up.’ (Tan et al., 2022, p.2)

In particular, the sixth-grade designers thought about how the board might help kindergarteners brighten their mood, since the school housed K-6th grade students. Furthermore, student designers also considered how the board would communicate STEM possibilities for students as they got older within the school, as one student noted: “they will know that they can do this kind of STEM work when they are in sixth grade, too” (Tan et al., 2022, p.2). Since the board was designed to be used by the entire school community with a goal of improving school morale, this example demonstrates students’ development of and engagement with STEM concepts and skills as a catalyst for change.

(2) Teacher draws on students’ cultural knowledge and capital to plan and implement culturally sustaining STEM lessons.

In addition to positioning students as experts and agentic changemakers in learning opportunities, the teacher must use students’ cultural knowledge and capital (Yosso, 2016) as a central reference point when planning and implementing lessons that serve to celebrate and sustain students’ culture (Paris, 2012; Paris & Alim, 2017). Drawing on the practice described above, wherein students are positioned as experts and agentic changemakers within STEM learning experiences, this practice goes beyond positioning, as students’ expert knowledge and potential to create change is further integrated into all aspects of STEM learning experiences, including the curricular materials with which they interact. Implementing this practice requires

that teachers build relationships with students and communities to understand the nuances of students' interests, identities, and culture and then incorporate such knowledge into planning for and enacting STEM learning experiences for youth. To build off the 6th grade science example cited above, the teacher in Calabrese Barton and Tan's (2009) study worked with both students and researchers to build a science unit related to students' lived experiences with food systems. Since the teacher had spent time co-planning with students, he was able to incorporate relevancy into his planning and instruction, as the authors describe below:

While traditional science lessons tend to follow the trajectory of learning content before searching for applicability, these lessons traced the reverse arc by focusing first on relevance and applicability while incorporating science content knowledge along the way (Calabrese Barton & Tan, 2009, p.70).

Thus, a search for applicability and relevancy before a lesson is enacted appears to be crucial to developing science curricular materials and instruction that connects students' lived experiences to science concepts and skills. As the authors note, and stated in the previous example, adjusting the science unit in such a way allowed for increased student achievement in the class. As compared to previous learning opportunities, incorporating students' cultural knowledge meant that "content understanding was much more deeply supported by a more authentic engagement and high participation levels by the students" (p.66).

(3) Teacher provides frequent and authentic opportunities for students to question and reimagine the status quo.

Opportunities for students to identify, critique, and reimagine the status quo (Freire, 1970; Ladson-Billings, 1995) requires teachers to first identify, investigate and take

responsibility for their position in maintaining a culture of power (Delpit, 1988). Such a culture of power plays out in the STEM classroom specifically in that:

for many students, engaging in STEM can be constrained and limited. Students from historically marginalized communities have cultural knowledge and experience that are highly relevant to doing STEM. However, the way in which STEM is often taught—through the discourse, practices, and activities promoted—does not always encourage and support students in leveraging their powerful expertise toward empowered learning in STEM. When students are expected to engage in STEM through power-mediated cultural norms, some people (e.g., boys, White students, monolingual English speakers) are unfairly privileged, while others (e.g., girls, students of color, emerging bilinguals) may be positioned as outsiders, which creates barriers to meaningful engagement and participation (Calabrese Barton & Tan, 2019).

Barriers to student participation only reify a harmful status quo in STEM fields where students from marginalized backgrounds are continuously excluded. However, such barriers can be addressed through careful examination of class discourse norms, expectations, and curricular materials. Inviting students into a process of reimagining the status quo, wherein all students, particularly those from marginalized backgrounds, are supported in seeing and experiencing themselves as successful STEM thinkers and doers increases the likelihood of achieving an ARSJ STEM educational and future career landscape for youth.

As an example of practical enactment, I explore Calabrese Barton and Tan's (2019) work with 6th grade students in an engineering-focused STEM unit. Within this unit, students were tasked with using engineering and design principles to address an issue of community concern in

their classroom. In this school setting, each classroom was equipped with a bathroom. However, these bathrooms did not include a lock and some students found themselves on the receiving end of other students opening the door when it was in use. To eliminate confusion and deter students from purposefully entering the bathroom while it was in use, students designed a solution called The Occupied. The Occupied worked through light-emitting diode (LED) lights attached to the wall outside of the bathroom. It then “used the bathroom lightbulb as a switch to activate a solar panel that powered the LEDs, connected by 12m of copper tape. When someone turned on the bathroom light, the LEDs lit up” (Calabrese Barton & Tan, 2019, p.617). This example not only demonstrates meaningful application of engineering and scientific content, but it also allowed students to experience success as doers of engineering, capable of identifying, addressing, and solving critical problems in their community. Such experiences support youth in reimagining what it means to do STEM and who participates and meaningfully contributes to the STEM community. The authors analyze this example through a framework of rightful presence, which asserts that students are invited into

legitimate membership in a classroom community because of who one is (not who one should be), in which the practices of that community work toward and support restructuring power dynamics toward more just ends through making injustice and social change visible (p.618).

Reimagining the status quo of participation in STEM learning through rightful presence potentiates more meaningful engagement for all students, thus supporting meaningful STEM concept and skill learning towards antiracist and socially just aims.

(4) Teacher supports students’ STEM identity development through representation and widened epistemic perspectives.

As students engage with and navigate STEM learning opportunities, they bring with them myriad ways of knowing, doing, and being which are continuously shaped by personal experiences, interests, and intersections of identity, such as race, class, and gender. Such experiences are sometimes easily integrated into youth's identities as STEM doers and thinkers, and other times students may struggle to find connections between how they view themselves and how they view someone who "does STEM." In the latter cases it is imperative for the teacher to support students' STEM identity development (e.g., Gholson & Robinson, 2019; Martin et al., 2010), which can be facilitated through both representation of BIPOC³ figures (Banks, 2015; Lee & Buxton, 2008; Pringle & McLaughlin, 2014) and widened epistemic perspectives (Bang et al., 2012). According to Martin and colleagues (2010), identity development cannot be ignored when considering how students are enculturated into the world of mathematics. As the authors state, we must consider "the inextricability of identity development – racial, mathematical, gender, and otherwise – and mathematics learning and development" (p.18).

Supporting students in developing identities as someone who "does STEM" requires the teacher to be critical and mindful of the images and portraits of scientists, technicians, engineers, and mathematicians which are presented to students. Thanks to popular media, culture, and textbooks, students may come to associate White, male figures with people who do and are successful in STEM. Such Eurocentric imagery only feeds into a harmful status quo that continuously excludes students of color in both implicit and explicit ways. However, it is not enough to simply show students pictures of people of color participating in STEM. Although representation is important, it must be coupled with a deep understanding of the context of power differentials within which a Eurocentric culture of STEM operates (Burgess, 2022; Mark, 2022).

³ BIPOC is a collective term referring to Black, Indigenous, and People of Color

Without embedding BIPOC representation in STEM in context, “whiteness is disguised as equity, thus upheld” (Burgess, 2022, p.985).

In an example of curricular enactment, researchers Gholson and Robinson (2019) explore the potential of using an identity-based mathematics curriculum in developing and transforming students’ perceptions of who does mathematics, as well as their place within mathematics culture. Mathematics for Justice, Identity and Metacognition (MaJIC) is a mathematics curriculum based on a restorative justice framework used in a summer bridge program consisting of primarily Black students at a large research university in the Midwest. The curriculum consists of three types of lessons: 1) mathematics for justice (e.g., using slope to explore rate of pay), 2) identity (e.g., debunking myths about what it means to be a math person), and 3) practices of mathematical cognition (e.g., strands of mathematical proficiency) (p. 351). For the purposes of exemplifying this ARSJ practice of developing STEM identity, I narrow in on a lesson within the “identity” strand that the authors delve into throughout the article. Within the identity strand, students spend time engaging with “The Silhouette Activity,” where students create posters depicting “the external messages they receive about mathematics and internal messages they tell themselves” (p.352). Discrepancies and alignment between the external and internal messaging

allow Black children to explore the tensions around their emotions (positive and negative), their hurts, and their hopes in a generative manner as they name and reflect on the inner negotiations of everyday life... and helps learners see the unique and common aspects of their mathematics learning experiences (p.355).

Although this activity in and of itself does not connect to mathematics concept and skill development explicitly, the use of such an activity is intended to right the harm done to students

of color within mathematics spaces throughout history and prime students to participate in mathematics learning spaces with a sense of belonging and competency. Beginning students' mathematics learning experiences in this way attempts to reorient students to a culture of mathematics within which they may have felt excluded from or marginalized in the past. As the authors argue:

these new insights and awareness can actually channel and build students' agency and navigational capacities as they continue to move through educational and social settings and systems. Specifically, when learners start to recognize patterns in the obstacles and resources that characterize their experiences, many begin developing strategies to maintain a more complete and grounded sense of self (p.355).

Supporting students in grounding themselves as someone who does and has the potential to be successful in STEM learning environments further potentiates the development of STEM concepts and skills towards ARSJ aims. Furthermore, supporting students' identity development and allowing them to see themselves in the work of STEM, allows for a more widened view of STEM epistemic possibilities and participation in a community of STEM practitioners both inside and outside of the classroom.

Coupling identity development with widened epistemic perspectives that incorporate non-Western perspectives (e.g., Bang et al., 2012; Bang & Medin, 2010) also begins to interrogate issues of power and oppression within STEM fields and widens the possibilities for students to see themselves as STEM doers and thinkers. As an example, Pugh and colleagues (2019) explored 40 Native American youths' experiences within a STEAM (Science, Technology, Engineering, Arts, and Mathematics) summer camp aimed at implementing land-

based learning programs. The program under study “focused on interrelations among forest and ocean ecosystems, particularly through waterways, and the kinds of impacts change climate change and ocean acidification is having on these systems” (p.429). The researchers designed opportunities for youth to enact “intergenerational cultural practices of walking, reading, and storying the land... [which] are routine practices in which individuals make and enact human–nature relations and apprentice children into epistemic, ontological, and axiological stances in human–nature relations” (p.427). One such opportunity included a mile-long walk from the cultural center to the beach where youth encountered numerous ecosystems and plant/animal interactions along the way. During the walk, youth “were asked to take the perspective of a plant and during the walk become that plant” (p.432). In doing so, youth explored their role within the ecosystem, as well as their interactions and relationships with other organisms and entities in the surrounding environment. One such outcome was that of identifying and defining the roles of keystone species throughout the walk. Youth came to embody each species and discussed what that species did for the ecosystem. For example, youth identified maple trees and stinging nettle as keystone species yet recognized that each plant had different characteristics. While the maple tree “gave maple and oxygen” to the rest of the forest, stinging nettle “give cordage, medicine, and take care of the forest” (p.440). These differing views of keystone species opened space for debate amongst youth as to what qualified as a keystone species. Furthermore, as the authors point out, within this case, “we see the forms of reasoning evident in discourse and patterns of interaction reflective of Indigenous knowledge systems as they may manifest in youth,” (p.445) further centering youths’ perspective-taking experiences in science sensemaking and building their identities as STEM doers and thinkers.

(5) *Teacher supports students in developing STEM tools to investigate community-related social justice issues.*

As agentic and capable STEM doers and thinkers, students should also be supported in developing STEM tools to investigate and address issues of social justice within their school and surrounding community (e.g., Calabrese Barton, 2003; Handley, 2021; Handley & Moje, 2020; Varelas et al., 2018). Connecting the development of STEM concepts and skills to community-related social justice issues increases the likelihood of a transformative educational experience for both youth and the surrounding community. Not only are students supported in developing STEM concepts and skills critical to engagement in STEM-related educational and career opportunities, but they are also supported in exploring how to use such tools for the betterment of their community and society writ large.

As an example, Benavides and colleagues (2023) explored students' use of engineering concepts and skills to address an issue of community concern in their school situated within a 6th grade curriculum entitled Engineering for Sustainable Communities (EfSC), which was designed with the following principles in mind (p.156):

- 1) Uses community members' ideas in engineering.
- 2) Helps the community solve their problems through engineering.
- 3) Cares about the environment.
- 4) Designs solutions for now and the future.

Although the authors describe three projects that students enacted in the curriculum, I narrow in on one example here: three female students developing a sustainable solution to address the problem of pushing and shoving in the hallways. In the article, the authors describe the process by which three girls identified and defined the problem of feeling unsafe in the hallways due to

overcrowding, pushing, and shoving. This problem was particularly salient for the girls because their “assigned seating was the farthest from the doorway in [their teacher’s] large room. As some of the last ones to exit each day, they explained how they were being shoved when leaving the room after class caught in the ‘traffic jam’ with incoming students” (p.160). Furthermore, the students would face disciplinary action for being late to their next class because of such “traffic jams”, rendering this a localized issue of social justice for the female students. Using an engineering design process of problem exploration and definition, sketching, prototyping, and iteration, students developed “The Hall Stoplight” which was modeled after the hand stop signs traffic controllers use to direct the flow of traffic. The Hall Stoplight could be controlled by their teacher and made use of LEDs to light up and direct students to stop and let students out of the classroom before the next group of students entered. To properly investigate this problem of community concern, the girls left the confines of the classroom, rendering themselves visible to the school community and “increasing the chances of being recognized by community members as girls engaging in engineering” (p.170). Furthermore, investigating this problem space allowed for the girls to be

engaged in the practice of flipping the gaze from behaviors and personal responsibility on students' parts (do not shove, do not push...) to the infrastructural inadequacies of the school building. The girls' projects revealed inadequacies such as...only one doorway to the hall for a double-sized classroom used simultaneously for students' entrances and exits. Their design process was a symbol of real and potential power sharing with school authorities (teachers, administrators) in engineering.

In this example, students were able to identify and remedy an issue of community concern using engineering tools. They not only utilized engineering and scientific concepts and skills, but they did so in a way that was deeply personal to them and impacted their school community.

Furthermore, this example demonstrates the potential for a single unit or lesson to draw on multiple ARSJ STEM teaching practices. Although I utilized this example to highlight the potential to engage students in addressing social justice concerns in their community through the development of STEM tools, it also shows how students were able to draw on their personal experiences, were positioned as experts and agentic changemakers, and were supported in developing identities as engineering doers and thinkers.

(6) Teacher critically examines STEM curricular materials and adapts as necessary to uncover bias and better connect to students' lived experiences.

The design and implementation of culturally sustaining lessons often requires the work of critically examining existing STEM curricular materials and making necessary adaptations (Au, 2011; McIntyre et al., 2001). As laid out by Burgess (2022), “positioning the science curriculum as a sterile, objective entity is deeply flawed, requiring work to truly create equitable science learning experiences for students of color rooted in social justice” (p.986). Such work can be done through careful analysis of STEM curricular materials and making the necessary adaptations to reflect more antiracist and socially just materials for students to interact with towards the development of meaningful and transformative STEM concepts and skills.

As an example, Mutegi (2011) interrogated science curricular materials aimed at developing an understanding of the food system entitled Linking Food and the Environment (LiFE) (see Koch et al., 2008) and makes recommendations towards more relevant and socially just aims. Throughout the article, Mutegi (2011) makes clear that he views “curricula (and

schools in general) as vehicles for social change” (p.306). In doing so, Mutegi (2011) described five types of mastery that must be addressed for curricular materials to be qualified as socially transformative: content, currency, context, critique, and conduct. In his analysis of the LiFE curriculum, the author points out that the materials are reform-based and geared towards a goal of “science for all.” Mutegi also states that the curriculum is novel with respect to the science content covered while maintaining relevancy for students. It is in this way that the curriculum attends to content and currency. However, Mutegi also pointed out that modifications could be made to better address context, critique, and conduct. As such, with respect to context, the author suggests:

In positioning students to master the context of a science topic we help them to answer the question, ‘In what ways are food systems important to people of African descent?’ One example of an area of study that could help students to address this question would be the study of food systems in non-Western cultures with a special focus on food systems throughout the African Diaspora. Herein students might explore the types of foods eaten by people of African descent throughout the world. They might also explore how those various groups of people obtain their food, how they prepare it, how they consume it, as well as the cultural norms governing the processes of obtaining, preparing and consuming food (p.311).

Here, Mutegi pointed out how asking questions related to non-Western cultures not only highlights relevancy for students, but also widens STEM epistemic norms and lenses (Bang et al., 2012). Through decentering whiteness, the curriculum becomes more socially transformative and builds on students’ cultural knowledge and capital. As Koch and colleagues (2008) point out,

“instruction that seriously builds on what students know and care about can serve as a hook that gives them ownership of the content being learned” (p.39), which in turn creates a greater potential for the development of STEM concepts and skills towards ARSJ aims.

(7) Teacher evaluates and assesses students’ STEM sensemaking through responsive and holistic measures.

Engaging in ARSJ STEM teaching practice necessitates that such practices reach all areas of teaching, including evaluation and assessment. Transforming the ways in which youth are engaged in STEM learning experiences must also be inclusive of the ways in which students are evaluated and assessed on their development of disciplinary concepts and skills. Without such attention, traditional written tests and other assessment measures run the risk of remaining decontextualized for many students and further upholding systems of White supremacy. Learning STEM in ARSJ ways requires a deep understanding of the contexts with which students are familiar and navigate their worlds. In defining this practice, I draw on Randall’s (2021) article on the impossibility of cultural neutrality in mathematics assessments and evaluation measures. As Randall (2021) pointed out: “we know that students—especially marginalized students—do not experience the world including schooling in ways that are context-free, so the question becomes *why do we insist that they experience their assessments in this way?*” (p.82, emphasis in original).

Although traditional, standardized evaluation and assessment measures are designed as context, and perhaps value, free, such “lack of context is an illusion rooted in white supremacist hegemony, and when the context is not clear (or seemingly not present), the implied context, historically, has been whiteness” (Randall, 2021, p.83). Thus, there is no such thing as ‘neutral’ when it comes to schooling and assessment, particularly when faced with seemingly objective

STEM disciplines, such as mathematics. Designing ARSJ STEM assessment and evaluation measures that adequately measure the whole of students' sensemaking, "requires that cultural words and expressions be included in our assessments" (Randall, 2021, p.85). Such cultural words and expressions need to encompass all students' experiences, not only White mainstream English (WME). However, when other cultural signifiers are removed from evaluation and assessment measures, we are often left with WME, rendering White culture as neutral while silently upholding systems of White supremacy. As an example, Randall (2021) pointed out that Pulitzer prize-winning hip-hop artist Kendrick Lamar's "lyrics would be considered culture-specific and inappropriate for inclusion on assessments" (p.85), while at the same time students may be asked to analyze the Eurocentric works from artists and authors such as Beethoven and Shakespeare.

As an example of practical enactment, Randall (2021) described how foundational calculations in mathematics, such as $2+2=4$, are not context or value-free:

Students are rarely taught ' $2 + 2 = 4$ ' absent of context. Indeed, it is the context that enables students to gain both the conceptual and algorithmic knowledge necessary to add $2 + 2$. There is always context associated with seemingly simple tasks such as ' $2 + 2$ ' even if test developers are unaware of the context or do not know what it is. That context, however, is what students refer to (in their own minds) when attempting that task (p.86).

Translating such an idea into practice, Randall (2021) provided an example of an adapted mathematics test question that includes context which speaks to "the different ways of knowing and thinking and doing that Black stakeholders possess and value" (p.85). The sample test question reads as follows:

Marcellus is cooking hot meals to hand out to a small group of twelve Black Lives Matter protesters demonstrating against separating families at the U.S./Mexico border. He is making a meal of rice, cornbread, and red beans. He wants to make enough red beans for each person to have more than $\frac{3}{4}$ cup. Determine whether each inequality or number line correctly models c , the number of red beans Marcellus needs to make (p.83).

In the example described above, students are effectively asked to determine 12 multiplied by $\frac{3}{4}$ and represent this number accurately on a number line and as an inequality. Such a problem could be designed in myriad ways to speak to students' context, interests, and identities. However, such a problem cannot be designed as culturally neutral or value free. Thus, teachers need to consider how evaluation and assessment measures can become more inclusive, antiracist, and socially just. Providing relevant context for students allows them to better situate such a problem in their own world, as well as recognize the applicability of such a calculation to their lived experiences outside of the mathematics classroom.

As indicated throughout the explication of ARSJ STEM teaching practices above, each practice can be inextricably linked to the others. For example, *designing learning opportunities that question the status quo* might require an educator to first *critically examine the curricular materials* made available to them, which would also require them to *draw on students' cultural knowledge and capital* and *position students as experts and agentic changemakers*. Then, an educator might also want to *design responsive evaluation and assessment measures* to gage students' sensemaking and how they have demonstrated mastery of *disciplinary tools to address community concerns*. All the while, the educator might also consider how such engagement

supports students in *developing disciplinary identities*. Thus, while the examples cited above were placed in distinct categories, decisions could have been made to place that same example under another practice. This is not to say that every activity or lesson can or should include each ARSJ STEM teaching practice. Such an ask or expectation might be unrealistic, especially for a pre-service or novice teacher. However, the examples cited above demonstrate how even one activity can touch upon at least one practice, hence providing a realistic starting point for pre-service and novice STEM educators. Furthermore, if viewing ARSJ STEM teaching practices from a unit perspective, as opposed to an activity or lesson perspective, then it becomes even more possible that all practices could be linked to each other and connected to the greater development of STEM concept and skill learning amongst youth.

Next, I turn to a review of empirical work that aims to support the development of the ARSJ STEM teaching practices described above.

Empirical Perspectives: Preparing Teachers for ARSJ STEM Teaching

Although pre-service teachers may encounter or seek out few opportunities to examine their own biases, power, and privilege prior to entering the university space, efforts to develop antiracist teaching practice can be seen in preparing educators for elementary settings (e.g., Goldin et al., 2021; Khasnabis et al., 2019). In a study with 36 preservice elementary teachers, Goldin and colleagues (2021) designed a “counterstory-based simulation to disrupt [teacher candidates’] colorblind ideologies and promote race-conscious asset-oriented interactions” (p.16). In doing so, the authors found that Norah, a White female preservice teacher, was able to recognize ways in which her own instruction influenced her students’ abilities to talk about race and racism, a recognition that did not exist prior to engaging in the simulation, according to pre-simulation data collection.

Opportunities to engage elementary preservice teachers in practice and reflection on antiracist teaching were also seen in a simulation where participants explored an art project wherein a Black student wanted to re-race the Mona Lisa as a Black woman but did not feel comfortable doing so based on the classroom environment (Khasnabis et al., 2019). Preservice teachers in the study discussed the project and learned about the student's desire to re-race the Mona Lisa through a conversation with a parent. Within this simulation, the authors found that preservice teachers started to work towards uncovering their own assumptions about the parent and student that they might not have seen otherwise, including uncovering the ways in which colorblindness permeated preservice teachers' reflections about the interaction. The authors' "analysis suggests that [teacher candidates], on their own, will avoid the difficult considerations of race and racialized ways of being" (p.291). Thus, these studies shed light on the need for new teachers to engage in both practice and reflection on antiracist teaching with targeted support from instructors and mentors, but they do not show the extent to which preservice teachers were able to take their learning into practice once in the routines of everyday classroom life.

Questioning and interrogating the racial biases of preservice teachers, the majority of whom are White (U.S. Department of Education, 2018), is a potential first step in building ARSJ STEM teaching practice. In the work of Pringle and McLaughlin (2014), preservice science teachers in a university methods course were asked to choose "who does science" based on photographs of two White males, an Asian man, and a Black woman. Resoundingly, the preservice teachers chose one of the two White males, stating that "he looks like the typical scientist" (p.193) when, in fact, the Black woman was an engineer and the only scientist out of the group. Based on this work, the authors contend that "preservice teachers should be given opportunities to develop images of scientists beyond the monoculture of White male dominance

in order to effectively implement science curriculum that acknowledges diversity” (p.195).

Instances such as these remind us how preservice teachers enter the university space with preconceived notions of teaching (Lortie, 1968, 1973), as well as with expectations of students from diverse backgrounds (Darling-Hammond et al., 2002). If preservice and early-career science teachers are not given opportunities “to participate in activities that might help them to challenge dominant culture orientations” (Turner & Drake, 2016, p.34), then Whitestream perspectives (Grande, 2003) and, in turn, racist ideas, will continue to permeate science learning environments.

Although the literature related to antiracist STEM teaching is sparse, prior research has investigated ways in which pre-service and beginning in-service STEM teachers develop justice-oriented teaching practice. Similar to Khasnabis and colleagues’ (2019) use of reflection to promote antiracist teaching practice, reflection is also a powerful tool for developing orientations to socially just teaching (Mensah, 2011; Rivera Maulucci, 2013). As an example, Rivera Maulucci (2013) documented one such reflective journey through a case study of Nicole, an African American, Caribbean woman, throughout her time in a science methods course taught by the author. In the paper, Rivera Maulucci defines “socially just teaching as an ongoing struggle for more caring, equitable, and agentic schooling at classroom (micro), school (meso), and community/society (macro) levels” (p.454). As a woman of color, Nicole originally viewed her role as a science teacher to prepare students for the world as it exists, drawing on her own experiences as a college freshman: “How ironic that the valedictorian of her senior class of 509 students couldn’t understand the basic plot of the *Iliad*... I felt unprepared. I felt cheated” (p. 464). Maulucci argued that, aided by reflective journaling, Nicole came to see her role as a future science educator as one of preparing students for “the world as it should be” (p.472), perhaps

where texts such as the Iliad are both understood, and their value critiqued. Similarly, Mensah (2011) studied three pre-service science teachers' approaches to teaching elements of a multicultural science curriculum (Gay, 2002; Ladson-Billings, 1995; Nieto, 1992). Mensah (2011) argued that we have not yet adequately populated "the teaching profession with excellent multicultural and culturally responsive teachers" (p.296) and allowing pre-service teachers the space to teach and reflect on practice is a potential way to fill this gap. Upon analyzing pre-service teachers' reflections on micro-teaching experiences, Mensah (2011) found that including not only students' interests, but also the interests of pre-service teachers, such as environmental racism, allowed pre-service teachers to plan and implement lessons that "challenge the status quo" (Ladson-Billings, 1995, p.160, as cited in Mensah, 2011, p.303).

Prior research on both pre-service and in-service teachers has also shown that reflecting on one's own practice potentiates a widened and more informed perspective on students in ways that move towards more ARSJ STEM teaching frameworks (Bianchini & Cavazos, 2007; Furman et al., 2012). Drawing on Cochran-Smith and Lytle's (1999) notion of teacher learning as iterations of building knowledge about practice, Bianchini and Cavazos (2007) highlight three opportunities to learn for new teachers: "from students, from one's own practice, and from participation in professional communities" (p.587). After participating in a teacher education program focused on these three dimensions of teacher learning, one study participant, Brian, continued to reflect on practice into his first years of teaching. As a result, he was able to "identify his students' interests and needs and, in response, to provide all with more rich and varied opportunities to learn science both inside and outside the classroom walls" (Bianchini & Cavazos, 2007, p.596), highlighting the need for *extended* opportunities for reflection and support into the first years as a teacher of record.

As seen in Furman, Calabrese Barton, and Muir's (2011) work, an Urban Science Education Fellow and co-author, Ben, worked closely with researchers to study and challenge his own beliefs when it came to teaching science in an urban setting, which included critically reflecting on his own emergent practice in developing place-based science curricula. In one lesson, co-authored by Ben and his mentor teacher, students were asked to debate the environmental impacts of organic versus industrial farming after class trips to the local farmers market and grocery store. Not only were students more participatory during the debate than in previous class sessions, but they also spoke "in their own words and us[ed] discussion skills that they often employed outside school" (p.160), emphasizing the potential to leverage students' cultural and community interests as assets for meaningful science learning focused on social justice issues.

In addition to reflecting on one's own practice, previous studies have explored the efficacy of designing opportunities for pre-service teachers to implement socially just teaching practice as part of developing orientations to practice (McCollough & Ramirez, 2012; Varelas et al., 2018). Across six semesters of data collection and 502 participants, McCollough and Ramirez (2012) studied the impacts of Family Science Learning Events (FSLEs) on pre-service science teachers' "perceived ability to develop and teach culturally responsive science lessons/presentations to diverse student populations as defined by gender, socioeconomic status (SES), language, and race/ethnicity" (p.445). To prepare for the FSLEs, pre-service science teachers adapted and created lesson plans related to nutrition in Hispanic neighborhoods, created materials in both English and Spanish, and prepared to "explain to the participants how the science related to the culture of Hispanic students" (p.446). Of note, the researchers found that pre-service science teachers experienced increased confidence, as well as increased self-efficacy

in relation to implementing responsive science lessons. Similarly, Varelas and colleagues (2018) designed a learning opportunity for 10 pre-service science teachers to participate in a “toxic tour” with students in a predominantly Hispanic neighborhood in Chicago. The “toxic tour,” focused on environmental racism, was an opportunity for pre-service teachers to “fram[e] science in relation to community issues” (p.61), and to identify “general structural factors contributing to the disenfranchisement” (p.69) of the students with whom they worked. From this experience, pre-service teachers “constructed ideas about teaching science that came closer to justice-centered science pedagogy” (p.75). These findings suggest that strong alignment between community and university coursework, as well as opportunities for pre-service teachers to experience success in connecting students’ interests and identities to science has the potential to support the development of socially just science teaching practices.

The studies explored thus far represent a teacher education space in which teacher educators are committed to supporting preservice teachers in developing ARSJ orientations to practice. However, as demonstrated in the introduction, traditional mentor teacher settings and school placements offer different and sometimes opposing contexts. As such, existing structures within mentor teachers’ classrooms present possible constraints when it comes to developing ARSJ STEM teaching practice. However, previous research has explored the potential for alignment across contexts as seen in professional development opportunities for mentors focused on issues of social justice (Bravo et al., 2014; Moore, 2008; Thompson et al., 2013). As an example, Bravo and colleagues (2014) studied the differences in approaches to practice between 65 preservice teachers in an intervention group and 45 preservice teachers in a control group. The 65 preservice teachers engaged in the intervention were randomly placed in a science methods course that “promotes teaching as a cultural practice, and attempts to address

instructional ruptures with the goal of promoting social justice through education” (p.605) *and* with a mentor teacher who underwent training to support the pre-service teacher in working towards such approaches to practice. Pre-service teachers placed in the control group received science methods instruction that did not integrate issues of diversity, though this was provided in a separate course. Utilizing pre- and post-survey data, researchers found that pre-service teachers in the intervention group held stronger beliefs about the efficacy of integrating cultural and linguistic diversity into science instruction than those in the control group, thus further highlighting the potential outcomes of university coursework and placement school context alignment.

Although alignment across coursework and placement sites presents opportunities to better support new teacher learning, studies have also explored the impact of pre-service teacher agency on orientations to practice (Moore, 2008; Thompson et al., 2013). In a study of 26 pre-service science teachers, Thompson, Windschitl, and Braaten (2013) explored sensemaking around movement between two seemingly disparate spaces: a methods course that focused on ambitious science teaching practices, including working on students’ ideas, and mentor teachers’ classrooms that “overwhelmingly emphasized traditional teaching practices and curriculum coverage as a primary concern” (p.3). Even though school placements exhibited more traditional and less critical pedagogies, Thompson and colleagues (2013) found that the extent to which preservice teachers took up ambitious practices into their first years as teachers of record had more to do with their mindsets or affiliations prior to enrollment in the methods course under study than with their experiences in mentor teachers’ classrooms. As laid out by researchers, “the teachers who integrated ambitious practices primarily affiliated with the people and the ideas associated with the university and induction contexts” (p.29), while teachers who did not

integrate such practices “worked to preserve primary membership in school science departments with more traditional visions of teaching” (p.30), highlighting the importance of prior experience and preservice teachers’ agency in enacting instruction atypical of traditional teaching.

Relatedly, Moore’s (2008) study of 23 preservice elementary science teachers enrolled in a methods course suggested that preservice teachers were capable of enacting socially just science instruction, but they “must take on a civil rights or social justice identity for teaching science” (p.592) to do so. Through analyzing reflective writing pieces and interviews after participation in a book club reading *Ways with Words* (Heath, 1983, as cited in Moore, 2008) as part of the methods course, Moore found that whereas some participants viewed themselves as capable of enacting change through science instruction, others did not view themselves as agentic at all. In response, Moore posits that preservice teachers should be supported in “constructing views of equity and social justice, along with developing science teacher identities and using science as a medium to effect change” (p.606). Both studies suggest that the ways in which preservice teachers view themselves as agentic (or not) within the larger context of mentor teachers’ classrooms and previous experiences matters when it comes to developing orientations to socially just teaching.

Although examining one’s power and privilege is an important component of developing ARSJ STEM teaching practice, particularly for White pre-service teachers, studies have shown that doing so comes with potential challenges for university instructors. According to Boatright-Horowitz and Soeung (2009), teaching about White privilege in a college setting could be met with negative course evaluations. In a study conducted with 456 White students in an introductory psychology course, the authors found that “participants evaluated the instructors teaching White privilege significantly more negatively” (p.575) than those who did not teach

about White privilege. Although there is no discussion of specific teaching methods used by the instructors, the authors contend that “White students need to be encouraged to confront their own racist tendencies and acknowledge their privileged statuses” (p.575). However, such activities have the potential to generate negative or painful feelings, particularly if White students are considering these ideas for the first time. To this end, the authors suggest that it is “important to examine the necessity of creating these negative emotions in order to facilitate attitude change about racism” (p.575), as well as developing specific tools and methods to do so. This finding underscores the desperate need to intervene on new teachers’ potentially unexamined biases, power, and privilege. Additionally, if this finding is any indication of the racial literacy pre-service teachers bring with them to university settings, then this is an untenable situation for those who plan to teach. If prospective teachers cannot examine their own race-based privilege, they may be less likely to meet their students’ needs. Thus, more needs to be done to prepare new STEM teachers to teach from both antiracist *and* socially just orientations.

Preparing ARSJ-Minded Pre-Service and Beginning In-Service STEM Teachers: Models of Teacher Education

In this section, I turn to research literature focused on teacher education models that have served to prepare STEM teachers over time. Because I hypothesize in this work that more connections between university and K-12 schooling contexts provides a more effective and meaningful experience for STEM teachers looking to develop ARSJ teaching practices, I focus on literature related to such models, namely lab schools, professional development schools, and teaching residencies. Throughout the review, I demonstrate how the elements of these models have both supported and constrained teacher learning and how TTS model draws on such traditions yet is decidedly different in its approach through a combination of university-based

embedded, extended, and place-based supports. Furthermore, I demonstrate how each model presents gaps in effectively preparing pre-service and beginning in-service STEM teachers to develop ARSJ practice specifically. I then turn to a discussion of medical models from which TTS model was built.

Laboratory Schools

Perhaps the earliest iteration of the university-school partnership, laboratory schools aimed to provide a context within which to test “working hypotheses” in educational theory (Dewey, 1900/1991). Modeled after teaching hospitals as sites for the training of medical professionals (National Council for the Accreditation of Teacher Education, 2001), the laboratory school was designed to “provide a center in which emerging philosophic, psychological, and pedagogical principles could be put to the test of educational action” (Childs, 1966, p. 96). Though instantiations and research on lab schools is relatively sparse today, the model gained popularity in the early 20th century. Attempting to “make a connection between theory and practice,” Dewey (1907) theorized lab schools as places where the university and the K-12 school engaged in a mutually beneficial relationship:

We want an even more intimate union here, so that **the University shall put all its resources at the disposition of the [school]**, contributing to the evolution of valuable subject-matter and right method, while **the school in turn will be a laboratory in which the student of education sees theories and ideas demonstrated, tested, criticised, enforced, and the evolution of new truths**. We want the school in its relation to the University to be a working model of a unified education (p.109, emphasis added).

Thus, the lab school was intended as a site for direct observation and experimentation of university-based educational theories through direct support and involvement by university

faculty and students. Such support and involvement included increased financial resources as compared to other institutions of education, which tended to produce laboratory schools as sites for “elite” education (Cucchiara, 2010). Additionally, lab school enrollment tended to reflect higher numbers of children of university faculty (Hausfather, 2001), further distancing lab schools from issues of educational inequity.

Historically, laboratory schools were designed to research and serve the development of early childhood education (Saracho, 2019), which is still reflected in the majority of research literature on the topic available today (e.g., McBride et al., 2012; Miller Marsh et al., 2020; Salazar Pérez et al., 2018). For example, Miller Marsh and colleagues (2020) drew on participatory action research and studied the design and implementation of community service projects at a laboratory school with three teachers and 60 preschool students ranging in age from three to six. Throughout the study, researchers observed teachers’ discussions with students as they brainstormed ideas for community service that would be meaningful to youth, enactment of the projects, and subsequent reflections with teachers and students. Researchers found that listening to student voice allowed for more meaningful and agentic experiences in community service projects, which included creating valentines for a nursing home, collecting litter in a local park, and cooking and serving food at a local shelter. Through these experiences, “children were given the opportunity to take on participatory citizenship, moving beyond personal responsibility to having a role in organizing themselves and others to act” (p.11), as well as discuss social justice issues such as homelessness and environmental stewardship. Although the study described here does not have explicit ties to teacher education, the lab school design appeared to allow for the potential of participatory action research to occur in a school setting. These findings

indicate the possibility of laboratory schools as sites of learning about teaching practice that centers youth and their experiences, even from a young age.

More recently, research literature on laboratory schools highlights a focus on students with exceptionalities (i.e., those with autism spectrum disorder, attention deficit disorder, and emotional impairments) and is seen in both education (Brown & Bartram, 2018; Smith & Irvine, 1999) and psychology literature (e.g., McGee et al., 2020; Oliver, 2010). The use of laboratory schools as sites for research across disciplines provides an opportunity for inter-disciplinary collaboration towards improved student learning outcomes. As an example, Brown and Bartram (2018) describe an early childhood laboratory school setting where child-serving professionals from a variety of fields, “including pediatric nursing, medicine, social work, exceptional student education, and speech-language pathology” (p.65) are encouraged to take part in research efforts throughout the school. First-year medical students from the participating university interested in pediatric medicine spent “time in the classrooms with young children, thereby gaining firsthand experience with developmental milestones and typical and atypical child development” (p.67). Although the authors do not report learning outcomes for either adolescents or medical students, they describe the program as so successful in popularity, the school added a more in-depth rotation for fourth year medical students. Most participating medical students reported “a new appreciation for the knowledge that teachers have about specific children; they questioned how, as future physicians, they could gain the ‘data’ about children’s behavior in classrooms” (p.67).

In addition to interdisciplinary collaboration example described in the previous paragraph, Cutler and colleagues (2012) studied laboratory schools as a site for inter-institutional collaborative inquiry between Kent State University and South Dakota State University lab schools. Across institutions, personnel in parallel roles (i.e., administrators, teachers, teacher

educators) collaborated on issues of educator preparation and professional development. Utilizing exit interviews from program participants, researchers found that participants across institutions were able to build a community of practice where “joint inquiry became a central mission of the group” and that such collaboration “strengthened each school’s practice with regard to school-wide research projects” (p.254). As an example, the authors described how both schools initially used Schön’s (1983) reflection-on-action tool to guide reflection between mentors and student teachers. However, due to the collaborative relationship across institutions, “South Dakota State University shared a protocol unfamiliar to Kent State University..., which added greater depth to the reflective process” (p.253). Although there is no focus on how these reflective discussions aided in furthering the development of pre-service and veteran teacher practice, the concept of cross-institutional lab school collaboration sheds light on the potential for larger partnerships across the country, emphasizing the importance of a shared mission as central to effective partnership.

Although the laboratory school model emphasizes the improvement of practice through research, such a focus is largely devoid of ARSJ teaching practice. Additionally, TTS’ focus on the development of new and veteran teachers further distinguishes this dissertation work from that of laboratory schools. While research is an important component of TTS model – this dissertation as an example – we must attend to the historicity of the relationship between research and communities of color, particularly the harm research efforts have caused in the past (e.g., Tuskegee Syphilis Study; Procurement and use of HeLa cells). Furthermore, TTS employs dual goals of student and teacher learning, wherein teacher learning does not stop with the completion of pre-service training. In the following section, I turn to a review of professional

development schools, which focuses more attention on the in-service years of teacher development.

Professional Development Schools

Introduced in the early-1990s, professional development schools (PDSs) are partnerships between university and K-12 school settings and serve as a site for collaboration between pre-service teachers, veteran teachers, and teacher educators (Darling-Hammond, 1994; Holmes Group, 1990). Similar to laboratory schools, PDSs aim to provide a productive clinical setting for the “rub between theory and practice” to occur (Darling-Hammond, 2008). Connecting theory and practice is theorized to occur by creating strong connections between pre-service, veteran teachers, and teacher educators through on-site training and blurring the lines between veteran teacher and teacher educator roles. Such focus on teacher learning while also being deeply committed to student learning is reminiscent of TTS model’s dual goals of student and teacher learning. Furthermore, Darling-Hammond (2008) asserted that PDSs are modeled after medical education models, thus drawing more connections between PDS and TTS models:

Like teaching hospitals, [professional development schools] aim to provide sites for state-of-the-art practice that are organized to support the training of new professionals, extend the professional development of veteran teachers, and sponsor collaborative research and inquiry (Darling-Hammond, 2008, p.94).

Although theoretical underpinnings across models are somewhat aligned, the enactment of an extended approach to teacher education varies between the two. In the late 1990s and early 2000s PDSs grew as a partnership between university-based teacher education sites and district public schools, offering extended models of teacher education and providing pre-service teachers with an additional training year beyond a typical educator preparation program (Darling-Hammond,

2000a, 2000b, 2008). This additional year of pre-service training, however, does not extend into the first years as a teacher of record, instead extending the time pre-service teachers spend with a mentor, as well as extending the time a pre-service teacher is expected to pay tuition to learn to become a teacher. Furthermore, such extension does not necessarily take place within the school at which pre-service teachers plan to teach.

Nonetheless, studies have shown that extension and embeddedness within professional development schools produces more successful and confident educators, who are also rated as more effective by their peers than those who did not participate in such a program (Andrew, 1990; Andrew & Schwab, 1995; Roybal-Lewis, 2022). In a longitudinal study comparing outcomes between graduates of four-year versus five-year programs within the same educator preparation program, authors Andrew and Schwab (1995) found that graduates of the five-year program were significantly more likely to both enter and remain in teaching when compared to their four-year counterparts. Similarly, Roybal-Lewis (2022) found that pre-service teachers who underwent training in a PDS exhibited strong commitments to the underlying goals of the program, including school community engagement, professionalism, and reflection, as per analysis of interview data with 43 participants. Although the author did not draw comparisons to a control group, the findings suggest that shared institutional goals provide a framework for pre-service teachers to develop aligned teaching philosophies and practice.

Contrastingly, other studies have shown that participation in a PDS during pre-service training does not always translate to more effective teachers (e.g., Reynolds et al., 2002). In a comparative study of 92 non-PDS graduates and 99 PDS graduates, authors Reynolds, Ross, and Rakow (2002) studied the impacts of participation in a PDS on teacher retention, effectiveness, and overall perception of professional preparation upon graduation. The authors found no

significant difference in retention rates between the two groups and effectiveness ratings, as conducted by administrators, produced mixed results across groups. However, PDS graduates were rated significantly higher by their principals on measures of sensitivity to “cultural and ethnic differences among students and balancing the varied demands of teaching” (p.299) when compared to their non-PDS counterparts. Furthermore, regardless of principal ratings of effectiveness, PDS graduates exhibited significantly higher levels of feelings of preparedness than non-PDS participants. Such findings suggest that although pre-service teachers encountered aligned and embedded supports from their university and K-12 settings within PDSs, the diversity of contexts participants encounter once they become a teacher of record may not continue to support the development of practice in the same way. Research on the extended nature of TTS model could begin to fill this gap in understanding how to better support beginning educators beyond the pre-service years.

Lastly, university-school partnerships through PDSs have been used to develop teaching practice focused on social justice (Cantor, 2002; Zenkov et al., 2013), although explicit attention to antiracist teaching was not found in the literature. For example, Zenkov and colleagues (2013) studied the impacts of participation in a PDS focused on issues of social justice and preparation for teaching in urban settings called Master of Urban Secondary Teaching (MUST). The authors begin by describing the criteria by which MUST participants are evaluated throughout their time in the program, placing emphasis on teacher reflection, activism, and culturally responsive pedagogy. The study focuses on the evaluation criterion of “social justice,” which is outlined as follows: “The MUST intern is a reflective, responsive teacher leader who successfully addresses the effects of race, class, gender, linguistic difference, ability, and sexual orientation on student achievement” (p.17). Analyzing data across 300 portfolio artifacts and essays, the authors found

that although participants did not arrive at the program with “clearly articulated concepts of social justice or with commitments to this ideal,” many participants were successful in “learning to understand and integrate [social justice] into their teaching and professional lives” (p.19). Thus, these findings suggest that strong programmatic commitments and evaluation measures have the potential to develop meaningful social justice minded educators.

Other Models of Teacher Education

In addition to the laboratory and PDS models described above, additional models of teacher education exist that divert from the traditional model described in the introduction. In this section, I explore alternative certification programs and teaching residencies. Both models of teacher education emphasize “on the job” training and largely bypass pre-service experience creating expedited pathways for those entering the teaching profession. Contrastingly, TTS model attempts to extend the training teachers receive, not shorten an already brief training period.

Alternative Certification Programs. For the purposes of defining TTS and the aims of this study, alternative certification programs do not serve a central role. Rather, I briefly point to literature on such programs to encompass a wide array of teacher preparation models that exist outside of traditional models that typically separate the university and K-12 schooling contexts, as well as to draw distinctions between alternative certification and TTS. In addition to the models described thus far, alternative certification programs, such as Teach for America (TFA, 2020) and Teachers of Tomorrow (Teachers of Tomorrow, 2021), attempt to fill gaps in teacher staffing and increase awareness or interest in schools in under-resourced urban or rural areas. Although many differences arise between alternative certification programs across the nation, most models emphasize “on the job” training and largely bypass traditional coursework

requirements, effectively shortening an already brief training period, particularly when compared with other professions such as medicine. For example, according to Teachers of Tomorrow's (2021) recruitment materials, classroom supports for first-year teachers in their alternative certification program consist of three classroom visits from a field supervisor and additional coaching available via email or phone calls. Furthermore, Teachers of Tomorrow advertises online training as the only necessary pre-requisite for entering the classroom with students: "Once you complete your self-paced online training, you will have gained the expertise and knowledge necessary to begin teaching in the classroom" (Michigan Teachers of Tomorrow, 2021). Not only is this approach to training insufficient to provide beginning educators with the pedagogical knowledge and expertise necessary to plan and enact transformative learning experiences for youth, but it also works to de-professionalize teaching – according to Teachers of Tomorrow (2021), anyone can be a teacher in as little as "weeks to months" depending on how quickly one proceeds through online learning materials.

Similarly, alternative teacher certification through Teach for America consists of six to eight weeks of summer school experience and professional development courses prior to starting the following school year as a teacher of record. Although such programs have the potential to provide school districts with an influx of new teachers, studies exploring the effectiveness of such programs on student learning outcomes have produced mixed results (e.g., Scott, Trujillo, & Rivera, 2016). Additionally, high teacher turnover rates and market-based approaches to solving educational inequities (Kang, 2020) renders such programs unsustainable and potentially harmful to students' K-12 learning experiences as new teachers "try on" pedagogical moves and skills.

Teacher Residency Models. A teacher residency is a model of teacher education that attempts to combine embedded, and in some cases, place-based and extended aspects of support.

Although recent research has begun to focus on teacher residencies (Berry, et al., 2008; Berry, et al., 2008; Gatti, 2019; Mentzer et al., 2019; Zeichner, 2010), few studies pay direct attention to issues of equity, justice, or STEM teaching. Thus, focusing inquiry on TTS begins to fill an important gap in the literature around developing ARSJ STEM teaching practices among pre-service and novice teachers.

Drawing explicit connections between school and community context and teacher education supports has the potential to increase coherence between university and school contexts, as well as better prepare teachers for specific contexts and students' needs. However, given the traditional time constraints of a teacher education program, adequately preparing new teachers to connect place and pedagogy is a difficult task. As laid out by Berry and colleagues (2008), "ten to twelve weeks somewhere near the end of one's preparation is simply not sufficient time for the quality preparation teachers need and their students deserve" (p.15). In response, the authors explore two teacher residency programs that aim to extend supports for new teachers into their first years as teachers of record: the Boston Teacher Residency and the Academy for Urban School Leadership. Both residency programs place new teachers in schools in Boston and Chicago, respectively. In the Boston Teacher Residency, certified teachers receive directed supports from program staff throughout two years in the program through a gradual release model. In the first year of teaching, new teachers are placed in a mentor teacher's classroom and co-teach alongside a veteran teacher. In the second year, new teachers have their own class, but consistently participate in professional development throughout the year. Within the Academy for Urban School Leadership, prospective teachers spend one year student teaching alongside a mentor teacher and work towards their master's in education from DePaul University. Upon graduation from the program, AUSL participants commit to teach in AUSL-

network Chicago Public Schools for four years. Researchers found that teachers in both residency programs were better at “reflecting on the quality of their teaching and collaboration with their colleagues” (p.20) than other teachers at the school. It is unclear, from the research I was able to review, however, how the nature of the professional development and program supports respond to advancing social justice and dismantling racism within the schools, districts, and communities that residents serve. Without such supports, residency programs such as these run the risk of reifying harmful schooling norms, such as Eurocentric STEM curricula.

In addition to exploring the nature of teacher residencies, Mentzer and colleagues (2018) compared two models of teacher education focused on preparing STEM teachers: a six-month fast-track program and a 1-year residency program. The authors found that STEM teacher residents were more prepared for high-needs areas than fast-track teachers but made no mention of ARSJ teaching practices. STEM teachers in the residency program were also more likely to enact inquiry-based instruction as opposed to direct or didactic instruction as seen in the fast-track participants. Thus, it appears that extended, embedded, and place-based supports do have the potential to better prepare teachers for carrying out instruction specific to the context within which they plan to teach.

Although many teacher residency programs are focused on filling employment gaps in large urban districts, none seem to be focused on preparing teachers for ARSJ STEM teaching specifically. Furthermore, none seem to provide extended opportunities for new teachers to continue working with mentors and university faculty beyond their first year or two in the classroom. The embedded, extended, and place-based nature of TTS, which will be further defined and expounded upon, make this a unique site for inquiry into one model of how the field

might better support new STEM teachers who are learning to develop and enact ARSJ teaching practices.

Medical Education Model

In addition to the teacher education models described above, TTS model draws heavily on elements of medical education. In a typical trajectory, medical students complete four years of medical school followed by a residency within a chosen specialty, with the potential for a fellowship with even more specialized training. Upon completion, doctors may achieve the designation of chief resident, supervising those in earlier years, and attending physician wherein they oversee groups of residents and fellows. Throughout this training trajectory, medical students and doctors spend time in both university and clinical settings through an extended-release model while working amongst intergenerational teams. These intergenerational teams consist of combinations of medical students, residents, fellows, and attendings, with the potential for near-peer interactions and learning within an intentionally designed community of practice. The design of such communities of practice allows prospective doctors to engage in numerous opportunities to learn well beyond their years as a medical student. Drawing connections between medical education and teacher education may serve to further professionalize teaching as something one learns beyond the pre-professional stage. Just as we would not expect a medical professional to diagnose and treat patients with only their pre-medical coursework as background, we cannot expect teachers to effectively support student learning with simply the knowledge and experience from pre-service training.

Research exploring the connections between medical and teacher education offer ways in which the medical model might be adapted to teacher education (e.g., Becher & Lefstein, 2021;

Purinton, 2012). Becher and Lefstein (2021) identify four aspects of the medical education model that could potentially serve the teacher education space (pp.2-3):

- (1) Teachers should engage in clinical reasoning to respond to complex situations arising in practice.
- (2) Recognize the centrality of the client in teaching.
- (3) Adhere to evidence-based standards of practice.
- (4) Teaching...is viewed as a complex activity which requires general knowledge (e.g., about student learning) and specialized knowledge particular to the domain of expertise.

Viewing teacher education in such a way works to professionalize teaching in that it positions the teacher as both expert and learner throughout one’s career. As teachers engage in clinical reasoning, they do so by drawing on their own general and specialized knowledge about both students and the subject they teach. Teachers also draw on evidence-based standards that emerge from ongoing research on teaching practice, similar to that of a physician staying up to date on medical journals and cutting-edge procedural techniques.

Similarly, Purinton (2012) explores possible connections between building professional expertise in medicine and teaching, and offers three parallels between medical and teacher education, as depicted in the table below (pp.354-355):

Table 2-1 Parallels between approaches to medical education and teacher education

Medical Education	Teacher Education
Preservice learning protocols and assessment of basic science/biomedical knowledge →	Preservice acquisition of basic knowledge of child and adolescent learning, particularly as related to specific subject areas
Preservice acquisition of clinical decision-making heuristics →	Preservice application of basic knowledge of classroom dynamics and individual learning situations
In-service biomedical and clinical knowledge transfer →	In-service professional development knowledge transfer

The parallels above suggest that teacher education follows a similar trajectory of that of medical education wherein preservice educators move from knowledge acquisition to knowledge transfer as they become teachers of record. Although there is no mention of intergenerational teams, the use of the term “in-service professional development” indicates a continuation of learning and support beyond the preservice years. According to Purinton (2012), the professionalization of teaching relies on adopting such practices, rather than his observations of attempts to quantify teacher education research. Instead, Purinton (2012) argues that education research should use “internally valued methods of research” (p.361) that apply to practitioner-use, similar to that of medical journals.

Extending the medical model to education is not without critique. In the case of extending medical models to education, the student becomes the client, or patient, where diagnostics, by way of assessment, understanding students’ sensemaking, and identifying differentiated learning needs, support the teacher in engaging in clinical reasoning. However, merely adopting “medical terms *client* and *problem* may suggest a deficit model of teaching” (Becher & Lefstein, 2021, p.3, emphasis in original). Furthermore, such language suggests a distinct power differential between the teacher and student, which may be appropriate in a medical setting but not necessarily in a learning environment. Thus, TTS model does not adopt such terms or stances when referring to students and their relationships to teachers. Rather, TTS model draws on intergenerational structures that serve to connect novices with veterans and better support the professionalization of teaching through extended and embedded learning opportunities. Additionally, “the terms *evidence-based* and *research-informed* may valorize scientific evidence over practitioner judgment” (Becher & Lefstein, 2021, p.3, emphasis in original), minimizing the effect of educator input and perhaps imposing a power differential

between researcher and educator. Yet, there are possibilities to include practitioner judgment in evidence-based and research-informed practice – practitioner judgment has the potential to *inform* evidence and research on teaching practice. The two do not need to remain mutually exclusive, particularly in TTS model that emphasizes intergenerational structures and institutional partnership.

The Teaching School Model: Embedded, Extended, and Place-Based Teacher Education

Drawing on and differentiating from the models of education described above, TTS model provides pre-service and beginning in-service STEM educators with the opportunity to pursue a three-year residency with embedded and place-based supports. In the sections that follow, I explore previous research on place-based and embedded models of teacher education. Then, I turn to a discussion of TTS model itself.

Place-Based Models of Teacher Education. In starting to connect university and school contexts around the development of ARSJ STEM teaching practices, place-based models of education might offer a framework for preparing new STEM teachers to teach in specific settings. Place-based education involves drawing on the community and temporally relevant concerns as a starting point for inquiry (Lowenstein et al., 2018; Smith & Sobel, 2010; Sobel, 2004). In the case of place-based *teacher* education, preservice and new teachers’ inquiries about problems of practice stem from the school and community setting in which they are learning to teach. As Darling-Hammond (2006) noted, “traditional versions of teacher education have often had students taking batches of front-loaded course work in isolation from practice and then adding a short dollop of student teaching to the end of the program” (p. 307). In shifting from a traditional to place-based model of teacher education, practice becomes infused with place rather than a separate experience. Azano and Stewart (2016) explored the preparation of rural teachers

in a place-based teacher education model. Using pre- and post-survey data, classroom observations, and reflections, the authors explored 11 preservice teachers' readiness to teach in rural schools as a result of placement in a rural setting and connections to a university methods course. The authors found that although teacher candidates entered the rural school space with deficit perspectives on students and culture, they were able to build relationships to leverage in designing and enacting responsive curricula. The authors suggest that "teacher educators make concerted efforts to dig deeply into the concepts of culture and place to explore how individual differences influence teaching and learning" (p.119).

Similarly, teacher educators at Eastern Michigan University have developed a place-based teacher education program to "to give teachers a sense of efficacy in using [place-based education] as a core instructional approach" (Lowenstein et al., 2018, p.47). Preservice teachers enrolled in the program are placed in cohorts and co-student teach in classrooms at Cody High School in Detroit. In addition to co-teaching, the teacher candidates take a three-course block together at EMU consisting of "a curriculum methods course, a school-based practicum in which candidates observe and help out in high school classrooms, and a social foundations course...that introduces candidates to an EcoJustice framework" (Lowenstein et al., 2018, p.47). The program not only encourages preservice teachers' development of place-based curricula, but it also uses Cody as both "text and teacher" (p.48) - the place itself is a critical space for new teachers to learn more about the school, students, and community.

Embedded Models of Teacher Education. In addition to place-based frameworks, adding an additional layer of embeddedness could potentially connect university and school contexts in more profound and meaningful ways. It is one thing for teacher education to be about place, but it is another for teacher education supports to be embedded *within place*. Such

embeddedness emphasizes the importance of place and context in learning to enact ARSJ STEM teaching practices. Such a model not only focuses on context-specific problems of practice, but also builds trusting relationships across partners and widens the potential to evaluate programmatic impact overtime. As an example, over a four-year implementation period, researchers at the University of Washington partnered with Blakeview Elementary School to make a vision for a “full-service community school” (Herrenkohl et al., 2019, p. 1) to come to life. Nestled within academic, family engagement, and health and wellness supports, the partnership served as a site for embedded teacher education. As described by the authors:

“...the full-service community model provided a unique opportunity to educate preservice teachers within the context of poverty-impacted schools, given that preservice teachers were not only working with educators during their student teaching but also collaborating with families, community-based organizations, and health and wellness providers offering services to students” (p.3, emphasis added).

This approach to preservice teacher education leverages stakeholder strengths beyond the university that serve to benefit both future teachers and their current students. The university-school partnership also provided “job-embedded professional development” for mathematics teachers that “resulted in a significant increase in the number of students meetings state standards in mathematics” (p.18). Thus, preservice teachers had the benefit of learning from veteran teachers who received such embedded supports. Situating teacher education within the full-service community school mediated preservice teachers’ “learning and their practices in their first positions after graduation” (p.18).

Throughout the partnership described above, researchers were committed to “working in partnership with school districts to ground teacher education in a community and school context”

(Napolitan et al., 2019, p. 4), elements of what Zeichner (2016) refers to as Teacher Preparation 3.0. In working towards a vision of more socially just teacher preparation, Zeichner distinguishes between three types of teacher education: 1.0, 2.0, and 3.0. The most ‘traditional’ mode of teacher training is known as Teacher Preparation 1.0, in which the university is viewed as the keeper of knowledge and bestows said knowledge onto pre-service teachers. Competing with this traditional model is Teacher Preparation 2.0, in which teacher candidates are put on a ‘fast-track’ to teach with little to no training ahead of becoming a teacher of record. Many programs classified as 2.0, such as Teach for America, “focus narrowly on teaching teacher candidates’ classroom management skills...and do not even address the issue of culturally responsive teaching” (p.152), all while placing teachers exclusively in high-poverty areas where responsive teaching is often overlooked or neglected in favor of dominant, Eurocentric norms. Addressing concerns raised in both 1.0 and 2.0 programs, Zeichner (2016) puts forth Teacher Preparation 3.0 as a model for advancing social justice and equity in teacher education. Within the 3.0 framework, “responsibility for educating teachers is shared more equally by different stakeholders (i.e., schools, universities, local communities)” (p.154), as seen in the university-school partnership outlined in Herrenkohl and colleagues’ work.

Similarly, the High Tech High (HTH) charter district, consisting of 13 schools in the San Diego area, developed an embedded teacher education model within their school district to train new teachers in their “teacher as designer” framework. Though not partnering with a university, HTH’s teacher training program allows interns to become credentialed teachers within the school, working towards their goal of increasing capacity for more teachers trained in project-based learning for their district. Within the embedded program, teacher candidates “share a space connected to one of HTH’s elementary schools, and students have the opportunity to practice

their learning on a daily basis in their work with K-12 students” (Griswold & Riordan, 2016, p. 26). Once teachers have completed the training program, “they enter High Tech High's induction program, a two-year teacher support program that focuses on classroom inquiry and includes continued work with a school-site mentor” (p.26).

Although the programs described above embed field-based supports for new teachers, they do not explicitly address the need for more ARSJ-oriented teachers in relation to STEM teacher preparation, which is of interest to my study. Given the literature on both embedded and place-based models of teacher education, I explore how such structures support new teacher development when these elements combine. What might an embedded *and* place-based model offer for STEM teacher education where new STEM teachers are both *prepared for and within* the school context where they plan to teach, and where ARSJ teaching is elevated as a central and shared goal by students and their families, teachers, teacher educators, and school leaders?

The Teaching School Model. My study takes place at Fairfield High School (FHS), a recently opened and newly designed model of teacher education focused on both K-12 student and teacher learning. In partnership between FHS and a nearby university, TTS was designed to serve as a space for place-based, embedded, and extended teacher education, reimagining supports for pre-service and early career teacher development that simultaneously supports both student and teacher learning while working towards educational justice. In contrast to traditional models of teacher education, TTS model (Figure 2-2, below) attempts to blur the lines between the university and K-12 school setting, creating a partnership focused on both student and teacher learning through ARSJ teaching practice.

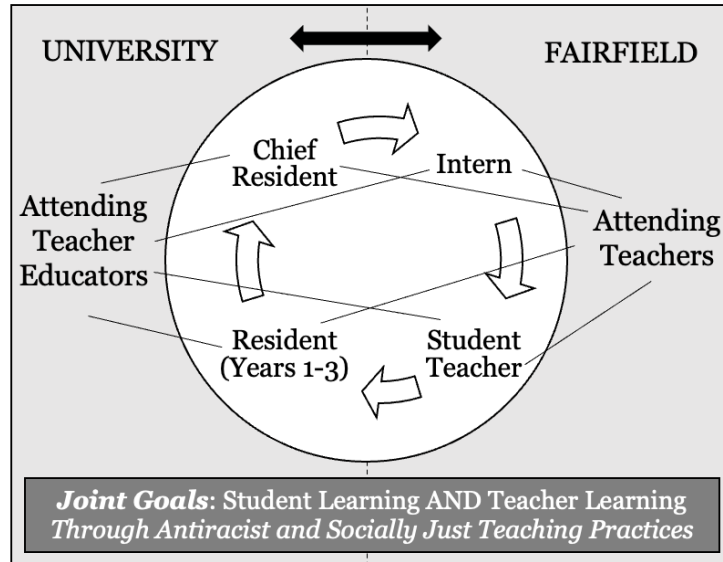


Figure 2-2 The Teaching School Model

Within TTS model of teacher education, pre-service teachers complete their internship and student teaching at Fairfield while simultaneously completing university coursework, some of which takes place on Fairfield’s campus. Borrowing language from medical education models, attending teachers and attending teacher educators, traditionally known as mentor teachers and field instructors, respectively, support teacher candidates on Fairfield’s campus as they increase instructional responsibility over time. Once student teaching is complete, however, attending teacher and attending teacher educator supports do not disappear, as is common in traditional models. Instead, fully certified teachers enter a teaching residency for three years where they continue to receive pedagogical support through coaching, co-planning, and professional development, indicated by the connecting lines in Figure 2-2. Ultimately, after three years, residents may enter a role as chief of residents where they continue to interact with and support near-peers in the intern through residency phases of their development.

In the following chapters, I further explore defining features of TTS with particular attention to the pre-service and beginning in-service STEM teachers learning to develop and

enact ARSJ STEM teaching practice, as well as the design and methodology used to explore such aims.

Chapter 3 Research Design and Methods

Introduction to Study

This dissertation studies teacher learning within a case of a unique reform model of educator preparation that makes use of extended, embedded, and placed-based supports called The Teaching School (TTS). Due to COVID-19 pandemic-related precautions, the entirety of the 2020-2021 school year was conducted online. Thus, all data collection efforts were conducted in a virtual format. The goals of this study were to a) explore participants' engagement with opportunities to learn ARSJ STEM teaching practices made available through TTS model and how they took up such opportunities in their practice, b) analyze participants' developing and emergent perceptions of ARSJ STEM teaching practice, and c) identify affordances and constraints of TTS model in supporting pre-service and beginning STEM teachers to teach in ARSJ ways.

As a reminder, the research questions guiding my study are:

1. What are the opportunities to learn ARSJ STEM teaching practices made available through The Teaching School model?
 - a. How do participants take up such opportunities to learn?
2. How do participants talk about their perceptions of ARSJ STEM teaching, as it relates to their teaching practice and development?
3. How does The Teaching School model support and constrain prospective and novice teacher development around ARSJ STEM teaching practices?

In this chapter I explicate the research design and methods used to explore my research questions. I begin by offering an overview of the central methodologies driving my inquiry: design-based research and ethnography. Then, I provide an overview of TTS model and the surrounding context and community, as well as study participants. Next, I explain the data sources I collected, as well as data analysis methods. I conclude the chapter by exploring reflexivity, subjectivity, and limitations of my work, as well as presenting the development of a key linkage chart.

Research Design and Methods

This research design draws on design-based research (DBR) and ethnographic methods to study participants' TTS experiences. Though not historically linked, both methods provide unique, yet complimentary perspectives on TTS design and research questions guiding my study. In the sections below, I delve deeper into the affordances of each method before describing TTS model, context, participants, and data collection methods in more detail.

Drawing on Design-Based Ethnographic Research to Study a Case of an Embedded, Extended, and Place-Based Model of Teacher Education

This dissertation, as well as the larger study within which it is situated, utilizes DBR methods in efforts to “better understand how to orchestrate innovative learning experiences...as well as to simultaneously develop new theoretical insights about the nature of learning” (Bell, 2004, p. 244). The extended nature of TTS model lends itself well to DBR, in that DBR pays particular attention to time (Engström, 2005, 2011). As TTS model grows over time, it also evolves within and between iterations, informed by ongoing research and by practical experience of the teachers, leaders, teacher educators, and researchers within the space. It is my goal to

contribute to this research effort by offering actionable implications that can be enacted in successive iterations of the project.

I approach this goal by analyzing data collected while I was deeply embedded and involved in the lives and experiences of TTS participants throughout the 2020-2021 virtual school year. Using ethnographic methods allowed me to pay particular attention to participants' experiences and meanings within the context of TTS model (Beach et al., 2018; Eisenhart, 1988; Erickson, 2006; Erickson et al., 1973). According to Eisenhart (1988), ethnographic methods draw on the idea that "all human activity is fundamentally a social and meaning-making experience... and that methods to investigate the experience must be modeled after or approximate it" (p.102). Thus, embedding oneself within the context of study allows for learning alongside others within a particular culture. Erickson (1973) describes the goal of such embeddedness as "making the familiar strange" (p.16) through uncovering the reasoning for participants' actions within a system, particularly if that system is already familiar to the researcher (e.g., a schooling environment, such as Fairfield).

When considering how TTS itself supports or constraints participant learning, design-based research (DBR) provided a framework for thinking about implications for TTS design. When considering participants' experiences within TTS model and analyzing their engagement with opportunities to learn, ethnographic methods allowed me to study TTS culture (Ghodsee, 2016) and describe participants' worlds as emergent and developing educators (Emerson et al., 2011). Thus, combining methods allowed for a fuller picture of participants' approaches to ARSJ STEM teaching, as well as their engagement in opportunities to learn and develop such practice. My hope is to produce a compelling narrative of participants' experiences within TTS to better design supports for pre-service and beginning teachers in efforts to better serve FHS students.

Sampling and Participants

This study examines teacher learning within a case of a unique reform model of teacher education through the lens of two TTS STEM residents in their first and second years, respectively, as well as two TTS student teachers, and two attending teachers. Below, I present the terms used to refer to participants throughout this dissertation.

TTS Term	Description
<i>Intern</i>	Pre-service teacher in their first semester working with students and attending teachers. Interns observe attendings' practice and support instructional goals through smaller tasks and building relationships with students.
<i>Student Teacher (ST)</i>	Pre-service teacher in their second or third semesters working with attending teachers and students. Over time, student teachers take on more instructional responsibility in the classroom and spend more time with their attending teacher and students.
<i>Resident</i>	Standard certified teacher of record in their first to third years of teaching. Residents take on full instructional responsibility and receive support from attending teacher educators and others in TTS community.
<i>Attending Teacher (AT)</i>	Commonly referred to as "mentor teachers," attending teachers model, analyze, evaluate, and support the development of practice with interns and student teachers.
<i>Attending Teacher Educator (ATE)</i>	On-site University staff and faculty that serve as support coaches for residents. ATEs observe resident practice, provide feedback, co-plan, and facilitate seminars aimed at resident learning.

Table 3-1 The Teaching School terms and descriptions.

Participants were purposefully selected (Light et al., 1990) based on a) their participation in TTS, b) their teaching of STEM subject matter, and c) their expressed interest in participating in additional data collection, such as interviews, outside of typical TTS responsibilities.

Although the school staff was relatively small at the time of data collection, there were two additional STEM teachers with whom I did not have a working research relationship and did not

include in this study. Two TTS residents, Kendall and Stella⁴, spent the 2020-2021 academic year receiving online coaching support from myself and Brooke, an additional researcher on the team. As such, I built the closest relationship to Kendall and Stella’s practice and personal stances towards teaching and learning. Additionally, I was able to collect numerous data sources related to Kendall and Stella’s practice in ways that I was unable to with Aaron and Iris’s practice during the pandemic-induced virtual school year. District policy precluded non-teaching personnel to enter student breakout rooms and made it difficult to attend teachers’ virtual classrooms outside of pre-determined researcher-practitioner pairs. I present participant-reported demographic information in Table 3-2 below.

Participant	Racial/Ethnic Identity	Pronouns	Subject Taught	Placement during 2020-2021 Academic Year
Aaron	White	He/Him	Mathematics	Student Teacher
Iris	Afro-Arab	She/Her	Mathematics	Student Teacher
Kendall	White	She/Her	Physical Science	1 st Year Resident
Kira	White	She/Her	Biology	Attending Teacher
Matthew	Black	He/Him	Mathematics	Attending Teacher
Stella	Nepali	She/Her	Human Centered Engineering and Design	2 nd Year Resident

Table 3-2 Participant demographics

I present Figure 3-1 below as a visual map of where participants were placed within TTS. This figure reflects Figure 2-2 (p.69), which illustrates TTS model, as well as the relationship between participants.

⁴ All names, excluding that of the author (Rachael), are pseudonyms.

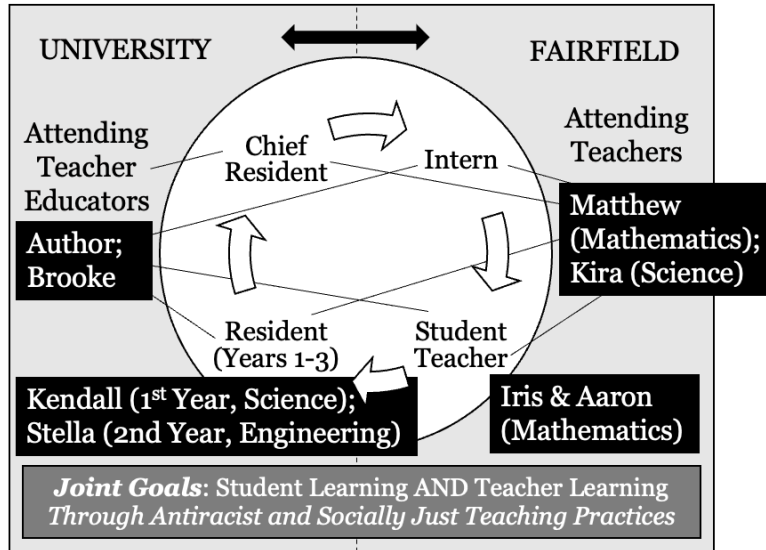


Figure 3-1 Participants mapped onto The Teaching School model.

Data Sources

My data collection was informed by TTS virtual learning opportunities made available to participants, such as coaching, co-planning, and observational feedback. I regularly documented residents’ online classroom practice through video recordings and field notes. I recorded residency support meetings, and residents maintained an online journal throughout the sessions. The residents, interns, and I engaged in regular informal, or *in situ*, interviewing in which I would follow up on conversations I had listened in on and teaching practices and moves I had observed. Additionally, I conducted formal semi-structured interviews at regular intervals throughout the school year to gain insight into participants’ personal experience within TTS, as well as their developing and evolving stances on ARSJ STEM teaching.

Participant	Interviews	Classes Recorded	Hours of Class Recordings	Field Notes	Journal Entries
Aaron	2	-	-	-	-
Iris	2	-	-	-	-
Kendall	3	71	72.46	87	19
Stella	3	49	40.21	52	19

Table 3-3 Data collection per participant

Semi-Structured Interviews

Interviews are “used to understand the perspective and goals of actors” and can “provide additional information that was missed in observation” (Maxwell, 2013, p. 102). As virtual classroom observations alone did not provide insight into participants’ theoretical stances, pedagogical goals, and decision making, it was important to make use of interviews to delve deeper into participant perceptions on TTS supports and their developing ARSJ STEM teaching practice. Both residents and student teachers were interviewed to “integrate multiple perspectives... to describe an organization,” such as TTS (Weiss, 1994, p. 17). To provide space for participants to explore their existing and developing stances on ARSJ STEM teaching and learning, as well as reflect on their TTS experiences, I conducted semi-structured interviews at regular intervals throughout the school year. Interviews were scheduled based on participants’ academic calendars. For residents, I conducted interviews at the beginning, middle, and end of the school year based on Fairfield’s semester schedule, which translated to October/November 2020, February 2021, and June 2021. Student teachers were interviewed based on the University’s semester schedule, at the end of fall and winter terms in December 2020 and April 2021, respectively. Sample interview protocols can be found in Appendices A and B.

Class Recordings and Observations

Over the 2020-2021 academic year, I collected over 110 hours of classroom recordings across 120 class periods in both Stella and Kendall’s virtual classrooms. Residents chose two class periods to be observed and recorded at their discretion. Kendall chose 1st and 7th hour, and Stella chose 6th and 7th hour. As a result of overlapping 7th hour classes, I observed and recorded Kendall’s 1st and 7th hour, as well as Stella’s 6th hour class, and Brooke recorded Stella’s 7th hour class. For the purposes of data analysis, I chose to focus on Stella’s 6th hour because I was

present for her instruction, and I chose Kendall's 1st hour because this class had a higher rate of student participation and a larger number of overall recordings. I collected more classroom recordings in Kendall's class than Stella's because Stella utilized asynchronous class periods on most Mondays beginning in January of 2021. Both Brooke and I recorded classes using QuickTime screen capture software as well as Zoom screen recordings and subsequently uploaded videos to a shared folder on a secure data storage site.

In addition to collecting video data, I documented classroom practice by writing descriptive field notes during each class, totaling 120 field notes across both residents' classes. I recorded 87 field notes in Kendall's classes throughout the year, in class periods ranging from 50 to 80 minutes. Similarly, I recorded 52 field notes in Stella's classes, most of which were 80 minutes because she chose to utilize asynchronous instruction during the shorter 50-minute class periods as of January 2021. As with any use of descriptive field notes, such documentation "involves issues of perception and interpretation" on the part of the researcher (Emerson, Fretz, & Shaw, 2011, p.6). As my analytic lens foregrounded teacher learning, and the virtual nature of the school year highlighted teacher actions more than student actions, my field notes heavily feature teacher moves and pedagogical decisions. All class recordings and associated field notes were organized and documented in a data log, which included the following categories: a) participant, b) class period, c) date, d) length of video (if applicable), e) summary of observation, and f) a link to the original recording or field note file stored on Box, a secure data organization site and repository.

The ability to document detailed descriptive field notes during class sessions was made more possible by the virtual nature of the school year. That being said, I also made use of reflective field notes (Erickson, 2006) to document instances of researcher-resident interactions

where in-the-moment documentation was not possible or would have been inappropriate. These reflective field notes were often constructed after one-on-one meetings with residents or participation in residency support meetings or monthly seminars with student teachers.

Journal Entries

Each week residents would virtually meet with attending teacher educators to discuss problems of practice, elements of ARSJ STEM teaching practices, and issues relevant to residents' immediate personal experiences and concerns throughout the school year. I planned for and led these sessions with Brooke, an additional attending teacher educator and researcher on the team, and we would often build in time at the beginning of our sessions for residents to journal in response to a prompt. Residents then used these journal entries as fodder for our ensuing discussion and would take the time to share out and respond to one another. Journals were maintained electronically through Google Docs. I made a copy of each Google Doc file and converted them to Microsoft Word documents for analysis. A list of journal prompts can be found in Appendix C.

Data Analysis

I analyzed data through an iterative coding process over the course of several months through constant comparative analysis (Glaser & Strauss, 1967) situated within a grounded theory approach (Charmaz, 2006). In this approach, I began by re-familiarizing myself with data sources, followed by multiple rounds of coding, and I then arranged coded data into categories based on what I found (Maxwell, 2013). Throughout and between each phase of analysis, I engaged in analytic and theoretical memo-writing, which I returned to frequently for the purposes of triangulation and documenting questions about validity and the shifting nature of my

findings (Maxwell, 1992; Maxwell, 2004). From the data, three distinct themes, which would be organized into findings chapters, emerged:

- 1) Participants' varied engagement with opportunities to learn ARSJ STEM teaching practices.
- 2) Participants' perspectives on the challenges and opportunities for connecting STEM and ARSJ teaching practice.
- 3) School culture's role in supporting and constraining the development of ARSJ STEM teaching practice.

I began the process of analysis by transcribing all interviews. Because I conducted interviews virtually via Zoom, I had the advantage of producing auto-generated captions from interview recordings. However, these auto-generated transcripts often incorrectly documented participants' thoughts, either through misspelling, omitting words, or placing punctuation at incorrect points in speech. Thus, I re-watched all interviews and cleaned up the transcripts, including appropriate punctuation at pauses, and inserted participant affect, such as [laughs], [nods], or exclamation points. After completing transcripts, I engaged in a first phase of analysis by reading through interview transcripts, residents' journals, observation summaries, and reflective field notes (Emerson et al., 2011). While reading each document, I recorded "preliminary jottings" (Saldaña, 2016, p. 21) in the form of in-text comments that captured my thoughts while staying as close to "the terms used by [participants] themselves" (Strauss, 1987, p.33) as possible. After engaging in preliminary analysis through jottings, I began initial coding (Charmaz, 2014; Saldaña, 2016) by making use of in vivo codes, which again served to connect closely with participants' words (Strauss, 1987) and attempted to "capture the meanings inherent in people's experiences" (Stringer, 2014, p. 140). Following a round of in vivo coding, I began

an iterative process of multiple rounds of focused coding where I reviewed codes and determined which made “the most analytic sense” (Charmaz, 2014, p. 138). Through this process, I began collapsing codes into larger categories while consistently returning to previous codes and documenting emerging findings through memos.

The use of Constant Comparative Analysis (CCA) allowed me to iteratively analyze and develop theory across participants and data sources. I began the coding process described above with interviews before moving on to records of participants’ practice, field notes, and journal entries. Given the large data corpus surrounding classroom observations, I made use of the data organization chart to first read through all summaries of classroom observations, which served as a proxy to observational field notes and classroom recordings. I recorded initial jottings within a copy of the data log document and I then looked for similarities and differences between initial interview codes and observation summaries. I was then able to eliminate observational data and identify points of interest based on the relevancy to my research questions.

Codes that resulted from initial interview analysis included ideas about participants’ perceptions and approaches to antiracist and socially just teaching and learning, as well as reflections on their developing practice and experiences within the Teaching School. I compiled a list of initial codes and engaged in a code mapping activity (Saldaña, 2016) to “bring meaning, structure, and order” to the data (Anfara, 2008, p.932, cited in Saldaña, 2016, p.218). Code mapping resulted in the categories and associated codes below:

Teacher Growth
Frustration and fears over district evaluation system
Willingness to engage in self-reflection and development of self-awareness
Planning for ARSJ STEM teaching and place-based instruction
Feelings of burnout and fatigue related to online schooling

School Culture
Desire to build stronger connections with colleagues

Desire to build stronger intergenerational connections between TTS participants Teacher-Teacher dynamics connected to varying definitions of ARSJ
Curriculum
Elements of developing ARSJ curricula: Approaching curricula adaptation and development through critiquing/critical lens Looking for and expanding BIPOC representation Adapting to management and planning in an online school year Adapting to students' needs in online school year Desire to make STEM curricula more project/place-based
Opportunities to Learn ARSJ STEM Teaching
Residency support meetings as moments of intergenerational learning Attending Teacher influence viewed as both positive and negative Desire to interact with colleagues more around ARSJ practice Learning from students in building relationships and developing ARSJ practice Desire for more definitional and programmatic alignment between university and FHS Desire for more actionable or observable ARSJ practices in university coursework
Online Schooling Context
Challenges in building school community during virtual instruction Challenges to student-student collaboration in online learning platform Limitations to classroom observations (both of own and colleagues' practice) Anxiety around shift back to in-person learning Advantages to in-the-moment coaching via online learning platform

Table 3-4 Code Mapping Example

I then took these codes and compared them to my initial jottings on records of practice and journal entries. Some initial jottings were aligned with and subsequently subsumed in codes, others warranted their own codes, and some codes were eventually dropped. This process was helpful in identifying alignment and misalignment between participants' perceptions and actions in approaches to teaching and learning, which served to support triangulation across data sources.

The coding process yielded six categories which were documented and refined through the iterative construction of category charts: a) learning from attending teachers and attending

teacher educators, b) STEM content-specific affordances and constraints in ARSJ teaching and learning, c) university-specific supports, d) perceived Teaching School model affordances and constraints, e) participant perceptions and definitions of ARSJ teaching and learning, and f) successes and challenges in ARSJ STEM teaching enactment. I organized these six categories into three major themes (stated at the beginning of this section) from which my findings chapters are organized. Table 3-5 (below) provides an example of a category chart with associated data and interpretive commentary.

Category: STEM Content-Specific Affordances and Constraints in ARSJ Teaching and Learning		
Participant/Data Type	Data	Interpretive Commentary
Stella/End of Year Interview, 6/29/21	I also think the last major piece would be centering the engineering work around social justice. So, that means when we think about problems they should be, you know, obviously centered in the community but also have a direct connection to social justice, which I think again, is something that I'm working on and need to do, you know, more concrete work on, but really making sure that the work that we do is tied to a particular issue of social justice or multiple issues of social justice as we're taking on these different projects.	<ul style="list-style-type: none"> - Engineering centered on social justice and community - More work to be done in curriculum - More direct connections to social justice - No mention of what makes social-justice focused engineering challenging, but acknowledgment of changes/improvements to be made
Stella/End of Year Interview, 6/29/21	If we're talking about bringing the community into the classroom, the community is the people who students care about, right. Like that is their community and so, bringing those people into the classroom is a big part of that. So, I think doing some component of an asynchronous presentation, though with feedback students have really mixed opinions on the format, was important because it's important that people can access our work, but also privileges people who can make it into the classroom at these really random slots of time, which is not most people. So, I also think having something where people who can't make it into the classroom can still engage with our work is really important, too.	<ul style="list-style-type: none"> - Current curricular format constrained meaningful community involvement - Shift towards more community involvement - Re-envision the classroom space as more socially just - Workshopping new format happened during residency coaching sessions

Kendall/Mid-Year Interview, 2/4/21	Redesigning [the curriculum] into looking more place-based and project-based. And with place-based, it's very different than engineering where, you know, the physical space is what they're looking at and yes, of course, the physical space at FHS for physical science is still important, but how can I, like other aspects of the community, that we know or take field trips to, or I don't know, I'm trying to figure out more connections like that.	<ul style="list-style-type: none"> - Comparing physical science curriculum to engineering → more place-based connections in engineering - Unsure of how to make more place-based connections - Trying to figure out more place-based connections
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Table 3-5 Data category and coding example

Developing the Key Linkage Chart

Throughout the development of codes and categories, I also developed a key linkage chart to draw major assertions from my data through multiple iterations (Erickson, 1985). I began by reviewing all codes assigned to a specific category and worked to draw patterns across my data sources related to such codes. Throughout analysis I used the key linkage chart to test my assertions and look for logical inconsistencies, as well as data outliers. Using constant comparative method allowed me to move between the key linkage chart and category charts regularly. Additionally, I continually updated the key linkage chart as new insights began to emerge based on analytic memo-writing and advising meetings. Over time, my major assertion and sub-assertions evolved into three themes that guided the development of my findings chapters. I used the following format as a template for my ongoing analysis:

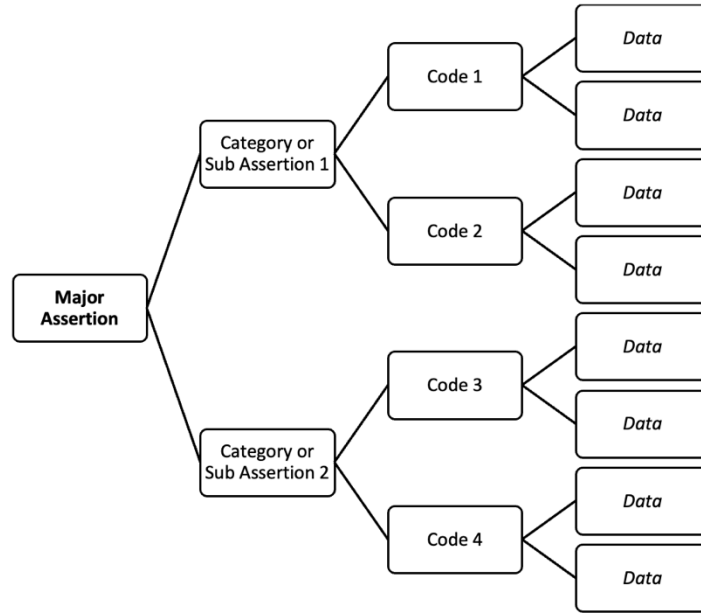


Figure 3-2 Key linkage chart template

Below, I present an early iteration of the key linkage chart (1/28/22) where I started to notice connections between my categories that would eventually allow for more collapse into three major themes. In the key linkage chart shown here, I was working with four categories that drew connections to my developing major assertion: attending teachers, content-specific affordances and constraints, model affordances and constraints, and district/school culture affordances and constraints. Upon creating this version, I realized that data related to attending teachers was present in multiple category charts I had been developing over time. These connections allowed me to collapse “attending teachers” into other categories to create larger themes around the role of attending teachers within the model, related to specific content area,

and within the school culture.

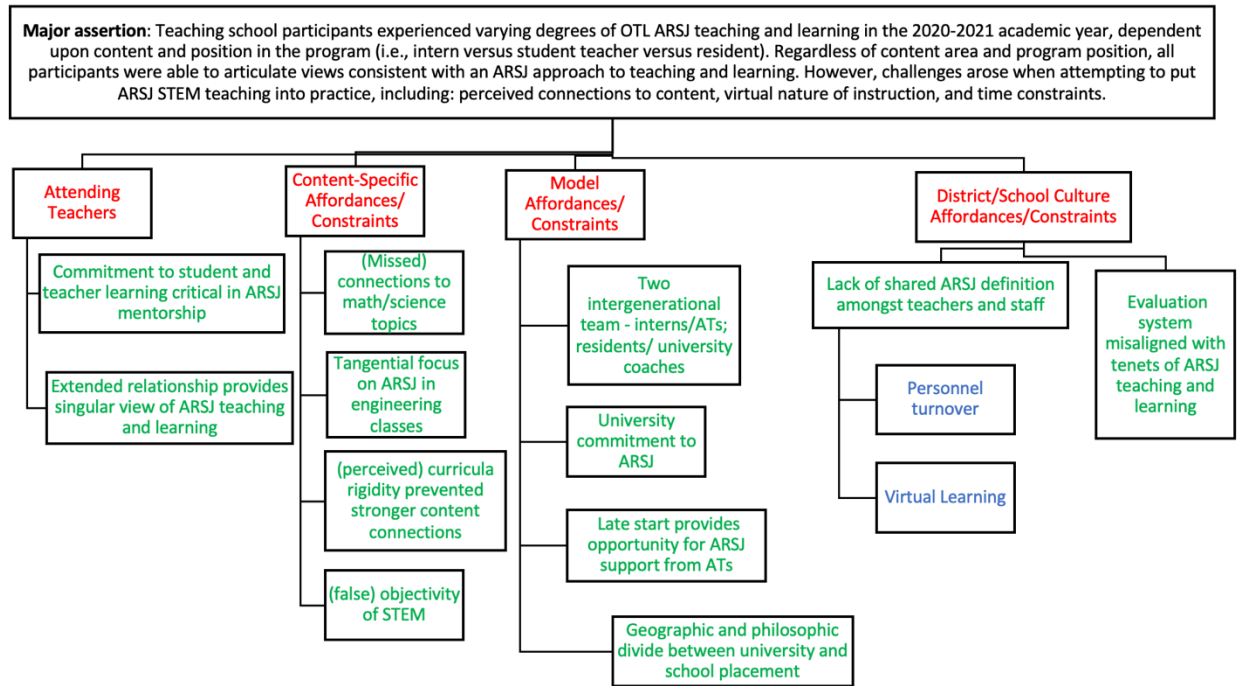


Figure 3-3 Key linkage chart development example, 1/28/22

Over time, my categories made way to sub-assertions that better described what I found within each category across data sources. In the sample below (Figure 3-4), I present a portion of the key linkage chart that resulted from analysis. I developed sub-assertions that aligned with the three themes that emerged from the data. In the chapters that follow, I present the full chart and use portions thereof to explicate my findings.

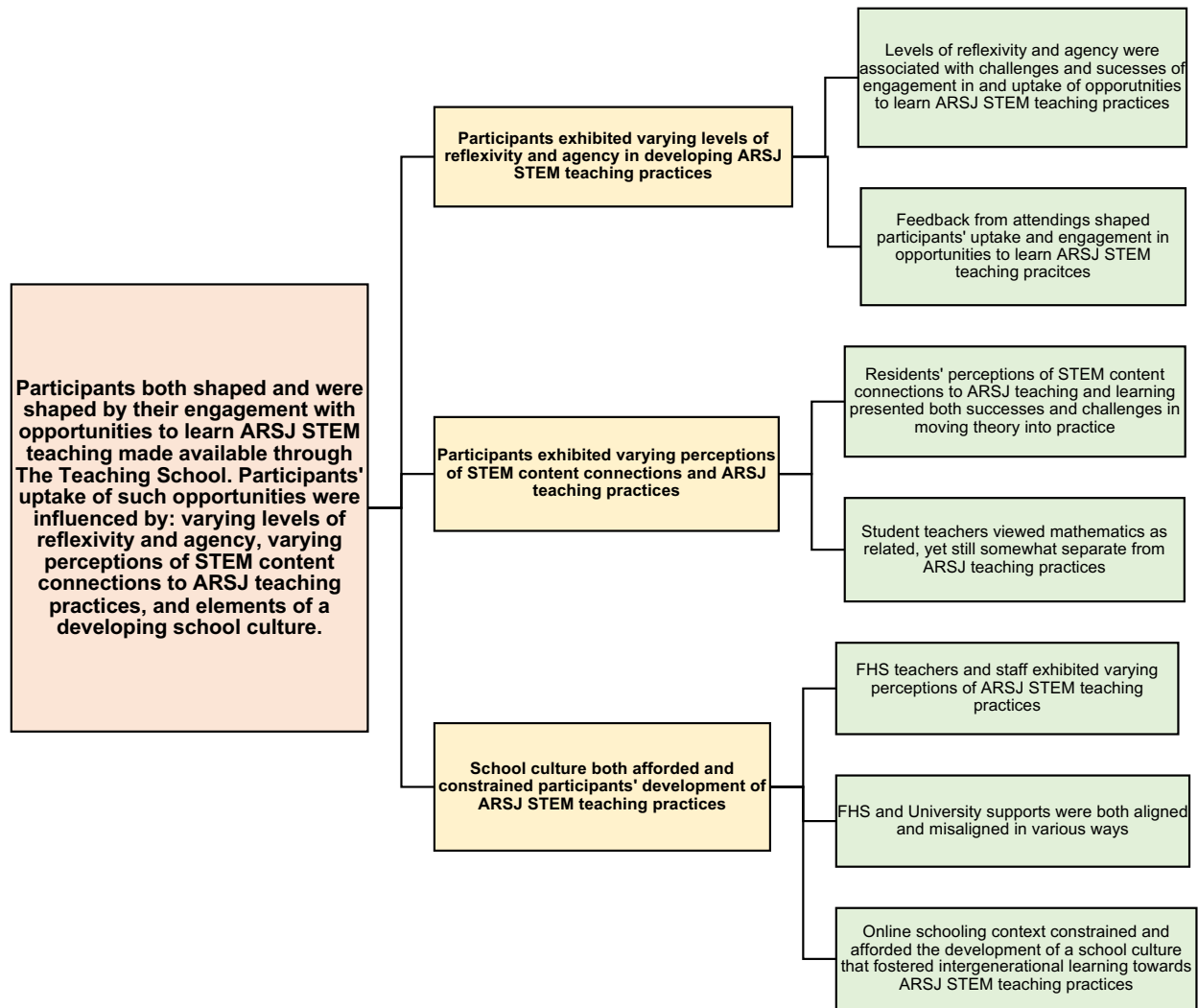


Figure 3-4 Key linkage chart sample

Reflexivity, Subjectivities, and Limitations

I come to this research as a former high school science teacher who taught across difference. As a White woman who served a predominantly Black student body, I always tried to position myself as a learner and a partner in seeking more just and equitable educational outcomes for youth. I am forever grateful for the difficult conversations about race, class, and power we engaged with as a school staff through ongoing professional development, and the relationships I built with both students and colleagues. My school deeply valued education for social justice and worked to celebrate “Black excellence” in every aspect of teaching and

learning, including curricular adaptations. Through this experience, I came to further understand my “standpoint” as a White woman in a position of power as teacher in relation to my students (Frankenberg, 1988; Harding, 1991). Furthermore, I began to view science as a cultural process that shapes and is shaped by Whiteness. I also experienced how difficult it was to adapt traditional science curricular materials and truly teach in ARSJ ways as a new teacher. These experiences primed me to have candid conversations with TTS participants about race, class, and power, and the role they play in teaching science, engineering, and math. I arrived at my doctoral program with a desire to learn more about how to better prepare science teachers to teach effectively across difference in antiracist and socially just ways. This desire motivated my dissertation work as I sought to understand how TTS model both supports and constrains the development of ARSJ STEM educators.

I designed the methods described throughout this chapter to mitigate threats to validity. In addition to methodological design and enactment, I also engaged in various activities to ensure validity. First, I engaged in consistent checks on researcher bias through memo-writing and regular advising meetings. My closeness to participants’ practice caused me to develop perspectives on their development over time, which could impact my reactivity as researcher (Miles & Huberman, 1994). However, as the researcher, I had to ensure that my selection and analysis of the data did not “fit [my] existing theory, goals, or pre-occupations” (Maxwell, 2013, p.124). One way I came to address this potential threat was through a search for and analysis of alternative explanations, asking, “What else might explain this?” when considering a piece of data (Erickson, 1986, p. 147). Considering all possible viewpoints brought more objectivity to my work and a new perspective on participants’ approaches to and enactment of practice I had not experienced during the year of data collection. Furthermore, my long-term involvement

(Maxwell, 2013) and collection of multiple data sources (Erickson, 1986) ensured a rich data cache from which to triangulate sources and better understand participants' experiences in TTS. Lastly, the iterative process of building a key linkage chart allowed me to visually map my emerging findings and search for connections across assertions and the relationship between data sources and participants. The full key linkage chart served to organize my findings chapters and can be found at the beginning of Chapter 4. Relevant segments of the key linkage chart will be presented at the beginning of each findings chapter.

This research is not without limitations. First and foremost, my analysis is missing student voice. Although I was interested in highlighting the experience of pre-service and beginning teachers, we know the work of teachers is deeply intertwined with the lives of students. Due to the virtual nature of the school year, I was limited in my ability to a) build relationships with students, and b) converse with students about their experiences with pre-service and beginning teachers, as well as their perceptions on ARSJ STEM teaching. Throughout the school year, most students rarely turned on their cameras and used the microphone to share out in class sparingly, choosing to participate via the chat instead. Teachers would often make use of break-out rooms to allow students to talk in small groups and collaborate on projects. Unfortunately, through technical and procedural limitations I was not allowed access to these spaces with students per district policy. Regardless of these limitations, this study serves as a foundation to employ future work that features student voice and experience. Secondly, the study features a relatively small number of participants. Given the developing nature of TTS, only two residents and two STEM student teachers were present during the year of data collection. This allowed me to develop close relationships to participants and meaningfully embed myself within residents' practice over an extended time period.

Following and working alongside these four participants allowed me to build relationships with others in the school setting and insight into the overarching school culture, the leadership team, and relationships between participants and attendings. This intensive, in-depth, and long-term analysis paves the way for follow-up studies of the multiple and diverse perspectives on ARSJ STEM teaching represented in the partnership as TTS grows.

Chapter 4 Building The Teaching School (in the Midst of a Pandemic): Context, Practices, and Participants' Perceptions of School Culture

In this chapter, I begin by presenting the full key linkage chart to demonstrate the analysis to be explored throughout Chapters 4, 5, and 6 (p.93). Based on my analysis, I assert that residents and student teachers' learning was shaped by their engagement with opportunities to learn ARSJ STEM teaching practices made available through TTS. Participants' uptake of such opportunities was influenced by varying levels of reflexivity and agency, varying perceptions of STEM content connections to ARSJ teaching practices, and elements of a developing school culture. The key linkage chart shown in Figure 4-1 is a visual representation of my findings and the relationship among and between assertions. In this chapter and the ones that follow, I break down this overarching assertion into three sub-assertions. First, in Chapter 4, I present elements of TTS build out and culture, laying a foundation for understanding participants' perceptions of and experiences with learning opportunities at TTS. I present data to show how the emerging and developing school culture both afforded and constrained residents' and student teachers' learning of ARSJ STEM teaching practices. I found FHS teachers, staff, and university supports exhibited varying levels of conceptual alignment in relation to ARSJ STEM teaching. Furthermore, the online school year limited the possibility for extended and meaningful intergenerational learning.

In Chapter 5, I explore participants' varying levels of reflexivity and agency as it relates to their approaches to practice and enactment of ARSJ STEM teaching practices. Participants' approaches to practice and engagement with opportunities to learn appeared to shape the degrees

of reflexivity and agency that I observed. Furthermore, reflexivity and agency shaped successes and challenges in taking up opportunities to learn, and residents' and student teachers' engagement in feedback with attendings.

In my last findings chapter (Chapter 6), I explore participants' perceptions of STEM content connections to ARSJ teaching practices and how this shaped their stances towards teaching and learning. Specifically, I found that residents' perceptions were associated with relative levels of success in designing and enacting ARSJ STEM teaching practice. Additionally, student teachers were given limited, yet meaningful opportunities to engage with ARSJ mathematics teaching practices with their attending teacher.

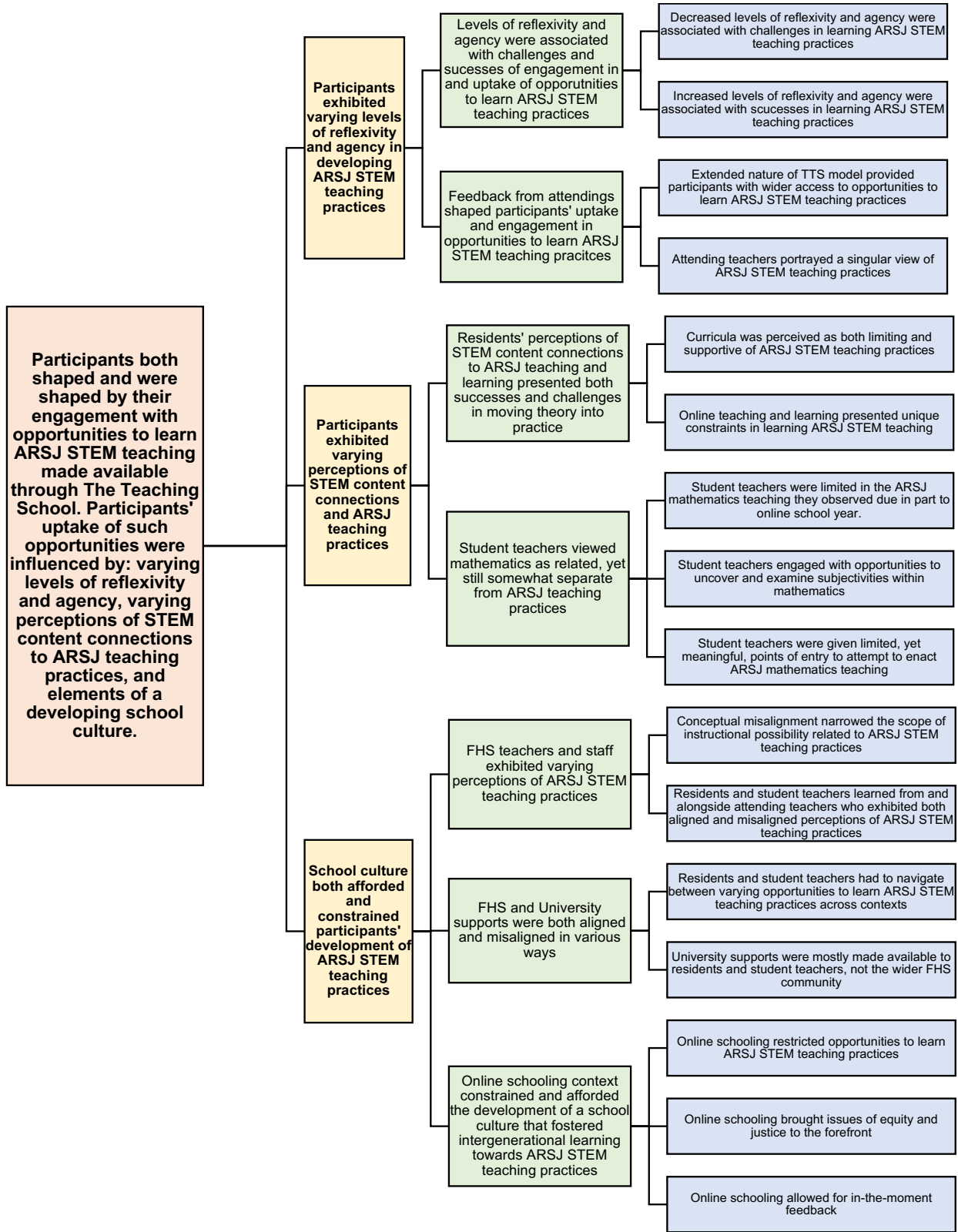


Figure 4-1 Key linkage chart

In the remainder of this chapter, I set up TTS context and take up the first sub-assertion, which explores participants’ perceptions of school culture, examining the ways in which residents and student teachers built and moved within Fairfield’s school culture during a pandemic-induced virtual school year. In doing so, I examine how school culture both afforded and constrained the development of ARSJ STEM teaching practices. In conclusion, I offer insights into areas of growth and recommendations for the greater teacher education community. I offer a segment of the key linkage chart below to offer a visual map of the findings presented in this chapter.

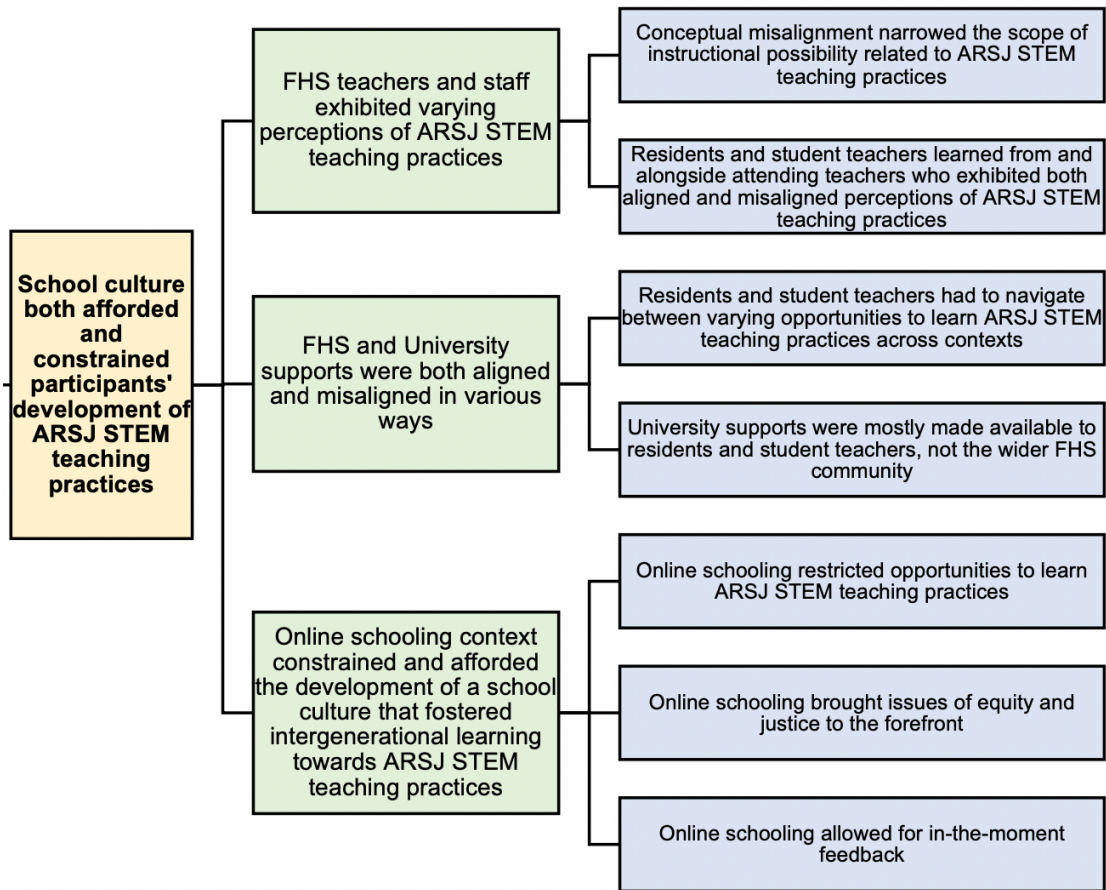


Figure 4-2 Chapter 4 key linkage chart segment

Context

As previously stated, this study took place over the course of a pandemic-induced virtual school year at Fairfield High School (FHS), which is in a large midwestern city and situated within the state's largest school district. Within FHS lives The Teaching School (TTS), which is a unique model of teacher education that attempts to bridge a divide between university and field-based experiences for those learning to teach from pre-service student teaching and into the first three years as a teacher of record. This study focuses on TTS model and how it supports and constrains STEM teacher learning through embedded, extended, and place-based supports focused on developing ARSJ STEM teaching practices. As such, I make use of the space below to further describe the Fairfield and TTS contexts by explicating its design, commitments, and practices. Then, I turn to an analysis of how participants experienced and perceived TTS culture.

Fairfield Context

Prior to opening its doors as a high school in the fall of 2019, the Fairfield campus was home to Fairfield College, a Catholic school for women founded in 1846. The school began offering college-level coursework in 1905, granted its first degrees in 1910, and was recognized by the state to confer teaching certificates in 1914 (College website, 2019). Thus, it is fitting that TTS found its home here, a site that has focused on teaching and teacher education from its inception. Set on 53 acres, Fairfield High School (FHS) and the surrounding limestone brick buildings were built in the early 1920s in a Tudor-Gothic fashion. Despite the virtual year of instruction, construction was happening in-person at FHS to outfit the historic building with a new layout and infrastructure to accommodate the needs of the high school, as well as the surrounding campus that would eventually house an early education center (2021) and elementary school (2022).

FHS is a public school situated within a large midwestern city in the largest urban district in the state. The district serves close to 50,000 students across 110 different schools throughout the city ranging from pre-kindergarten to 12th grade. At the time of study, Fairfield was home to 210 students across ninth and tenth grades with close to 60% of students qualifying for free or reduced-price lunch (nces.ed.gov, 2020), lower than the district average of 78% (District website, 2020). The overwhelming majority of students identify as Black, with 5 students identifying as White and 1 student identifying as American Indian/Alaskan Native. Across district schools in the 2020-2021 school year, 14.9% of students were classified as “proficient” on the Scholastic Aptitude Test (SAT) ([state]schooldata.org, 2021).

Design of the Teaching School

TTS model was designed through ongoing collaborative efforts between researchers, teacher educators, university faculty, and school district personnel. Such efforts have brought forth a mission statement, shared below:

TTS’s mission is to elevate the profession of teaching by creating a collaborative, sustainable, and translatable model of teacher preparation that extends and deepens teachers’ opportunities for professional learning. Teaching for social justice is at the center of this model, animating both its method and its substance. By embedding TTS in a PreK-12 school context, and by focusing simultaneously on the learning and development of young people and of their teachers, we bridge research with practice, teacher with learner, teacher educator with practitioner (TTS Design Session, 2/11/21).

TTS aims to professionalize teaching through embedded, extended, and place-based opportunities to learn for both K-12 students and teachers. Emphasizing dual goals of student and teacher learning highlights attempts to bridge the divide between K-12 and university

settings often seen in traditional models of teacher education. Furthermore, centering social justice works to guide approaches to practice and the opportunities to learn made available for pre-service and beginning in-service teachers.

It is important to note that all TTS design elements, including the features, commitments, and principles outlined below, were intended to be enacted and developed through in-person learning experiences. Thus, as the ideal TTS design is laid out here, data analysis showed that not all components were able to be implemented with fidelity. Perhaps most notably, *building communities of practice in which teachers learn and practice with each other, rather than in isolation* (TTS Commitments, 2/11/21, below) was made near impossible to implement throughout the 2020-2021 virtual school year. Pandemic-imposed distance learning not only isolated teachers and made it more difficult to cultivate communities of practice across the school, but doing so led to difficulties in enacting features, such as *co-teaching within classrooms* and *opportunities for mentors, field instructors, and novices to discuss practice together* (TTS Features, 2/11/21, below). I explicate TTS features, commitments, and principles below.

The Teaching School Features

The features laid out below serve to provide elements of the model that begin to animate the mission statement laid out above. The features are separated into conceptual/content features and structural features. Conceptual/content features encompass the approaches to practice and opportunities to learn made available at Fairfield through TTS. Structural features speak more to the types of systems participants engage in as they move through the model over time. For example, *co-teaching* and *professional development* are both conceptual features that support opportunities for participants to learn how to teach and develop practice throughout their time in

TTS. By contrast, *long-term placement*, as well as the *three-year residency*, are structural features that support the development of and participation in communities of practice over time. As previously stated, the features outlined below reflect TTS designers’ vision for the school, not necessarily how it was enacted in the nascent and unanticipated virtual year of data collection. In the following chapter (chapter 5), I lay out all structures that served as opportunities to learn for participants during the 2020-2021 virtual school year.

Conceptual/Content Features
Inquiry-based, project-based, and place-based teaching and learning <ul style="list-style-type: none"> - Drawing on evidence-based best practices to support teaching and learning - Utilizing Fairfield’s campus and surrounding communities to support learning - Developing and enacting solutions to community concerns using disciplinary tools and skills
Co-teaching model within classrooms <ul style="list-style-type: none"> - Student teachers and attendings act as intergenerational teams - Attending teacher educators support teaching and learning through co-teaching with residents at appropriate times throughout the school year
Professional development and workshops <ul style="list-style-type: none"> - Relevant Workshops on Teaching School goals: embedded mentorship, in-the-moment feedback/intervention support, novice teacher development, integration of community supports in classrooms - Mentor teacher specialties: strong mentorship, inquiry-based teaching, knowledge of students and community
Daily check-in points about teaching <ul style="list-style-type: none"> - Morning report - Teacher discussions - Grade level, team meetings - Case conferences, video analysis
Evidence-based decisions <ul style="list-style-type: none"> - Using principles of design-based research, we (re)design, evaluate, and improve programming and school approaches based on outcomes for young people and families
Meaningful, empowering social justice experiences for students and teachers <ul style="list-style-type: none"> - Students have numerous and varied opportunities in and out of school to learn about themselves and about the world and how to create change (i.e., field trips, social activism and change, college going experiences, career learning) - Teachers have choice and expertise in designing and highlighting these opportunities for students
Structural Features
Embedded, relevant, timely assessment <ul style="list-style-type: none"> - Longitudinal assessment: “Learning to Teach” Growth Competencies - In-the-moment intervention on novice practice - Embedded field work seminars

Long-term placement in City Teaching Pathway <ul style="list-style-type: none"> - Continued development of community of practice - Longstanding relationships - Community building and community understandings
Opportunities for mentors, field instructors, and novices to discuss teaching practice together <ul style="list-style-type: none"> - Journal club - Embedded field work seminar - Seminars and case conferences focused on problems of practice
Three-year residency <ul style="list-style-type: none"> - Opportunity for continued support and growth during the first three years of teaching - Creation of a community of practice

Table 4-1 Teaching School Features, 2/11/21.

The Teaching School Commitments and Principles

In addition to developing a mission statement and features, TTS designers developed a list of nine commitments that make the work of the mission statement and its features more specific. The commitments, shared below, begin to identify how elements of the mission statement appear and become animated in practice. Each commitment is accompanied by a set of principles that describe how such commitments begin to play out in practice and guide the enactment of each commitment. I highlight the second commitment, Antiracist and Socially Just Teaching, as this is a focus for my study. As it is stated in the mission statement and commitments, TTS is committed to “preparing and supporting teachers to enact antiracist and socially just teaching” (TTS Design Session, 2/11/21). Thus, I explore how and to what extent this commitment was enacted within TTS model through the lens of participants’ experiences as learners and teachers. Furthermore, each principle outlined below alludes to practices that support novice and beginning teacher training and development. Although space and the focus of this dissertation preclude me from exemplifying all nine commitments through the lens of practices, the ARSJ STEM teaching practices laid out in earlier chapters serve as a connection to Commitment Two: Antiracist and Socially Just Teaching. I view the seven ARSJ STEM teaching

practices as the intended enactment of Commitment Two and its associated principles. All nine commitments and accompanying principles are outlined below (Table 4-2).

Commitment One	<i>Principles</i>
<p>We commit to preparing and supporting educators to enact high-quality and inquiry-based teaching.</p>	1. High-quality and inquiry-based teaching is defined by what we know about how deep learning occurs.
	2. High-quality and inquiry-based teaching is necessarily anti-racist and socially just in both its stance and substance.
	3. To learn to teach well, novice teachers need scaffolded opportunities to learn from their own practice, in addition to seeing strong models of high-quality, inquiry-based teaching.
	4. It takes time to learn how to teach well.
	5. All teachers—and especially novice teachers—need access to high-quality curricular materials and support.
Commitment Two	<i>Principles</i>
<p>We commit to preparing and supporting educators to enact anti-racist and socially just teaching.</p>	1. All teachers and teacher educators must engage in frequent reflection on their own cultural and social identities vis-à-vis those of the school’s students and families, actively seeking to understand and to unsettle power disparities associated with those identities.
	2. Anti-racist teachers and teacher educators employ culturally-sustaining, humanizing approaches to their instructional practice and curricular design, their relationships with students and families, and their classroom management and other efforts to ensure classroom communities of collective care.
	3. A well-prepared teacher has commitments and skills related to learning about the backgrounds, goals, needs, beliefs, and motivations of each learner and family in their care, and knows how to leverage the strengths and resources of students, families, and the local community toward collective uplift.
	4. All teachers and teacher educators must be able to understand and recognize the ways patterns and structures of inequality, dehumanization, and oppression impact teaching and learning, and be skillfully prepared with the practices and dispositions required to interrupt these patterns through both teaching and advocacy.
Commitment Three	<i>Principles</i>
<p>We commit to preparing educators to work for the public good, and within the realities of an existing public school system.</p>	1. We think and act in close partnership with our colleagues and stakeholders at Fairfield and City School District, carefully considering the effects of our decisions on all of the positionalities therein (students, teachers, school leaders, community members, etc.).
	2. Public schools and institutions of higher education exist within larger systems and are accountable to the goals and directives

	of those systems—a reality that has significant implications for our collective work.
	3. The Teaching School, embedded in a public school system, prepares teachers for navigating—and, when necessary, challenging—larger systems of schooling in order to better serve students and families.
	4. The Teaching School, in partnership with the school, prepares educators who are committed to challenging the inequities of society, in part by fostering their students’ self-efficacy as change-makers and community leaders (see Commitment 5).

Commitment Four	<i>Principles</i>
We commit to preparing educators who recognize and model their power as collaborative change-makers, as leaders, and as learners both inside and outside of school buildings.	1. Experienced, attending teachers need to see themselves as “change-makers,” and novice teachers need to see strong models of “teacher-as-change-maker”—i.e., leaders and public servants who take visible, concrete steps towards equity and justice in their daily practice, and who do so with humility and a willingness to learn from and work with others.
	2. Teaching is advocacy work and requires teachers who are dedicated to working with all school stakeholders, including students and families, to create a fairer, better school.
	3. By modeling their power as change-makers, including in their instruction, teachers illustrate and emulate for students and novice teachers how to take action against structures of inequality, dehumanization, and oppression and how to share power with others along the way.

Commitment Five	<i>Principles</i>
We commit to preparing teachers who understand young people of all ages as powerful actors in and on the world, and who work daily to strengthen children’s work as change-makers and sense-makers.	1. Children and young people are brilliant, creative, and resourceful and must be provided frequent opportunities to be positioned as change-makers and sense-makers, and not merely as receivers of information.
	2. All teachers and teacher educators share the goal of leveraging teaching and learning toward supporting youth to recognize and exercise their power to advance justice and wellbeing in their own lives, and in the lives of others.
	3. Teachers and teacher educators must be provided frequent and meaningful opportunities to experience children’s expertise and capabilities inside and outside of the classroom, challenging any pre-conceived beliefs of children’s limitations that they bring to their work.
	4. Schools and classrooms must continuously and fervently resist any practices or policies that diminish young people’s personhood, their understanding of their own power, and their right to self-determination.

Commitment Six	<i>Principles</i>
	1. Context is an essential part of the teacher education curriculum.

We commit to enacting embedded, place-based, responsive teacher education.	2. We work in partnership with the communities in which we are embedded, and we are responsive to local circumstances, resources, and needs.
	3. Novice teachers must receive opportunities to learn about the communities (classroom, school, neighborhood, city) in which they are embedded and to practice incorporating that knowledge into their teaching.
	4. University coursework and field experiences must be coherent, complementary, and integrated; for example, university teacher educators must model inquiry-based, anti-racist teaching practices.

Commitment Seven	<i>Principles</i>
We commit to supporting novice teachers by providing frequent, targeted, and timely feedback using meaningful and embedded formative and summative assessments.	1. Frequent, targeted feedback over time supports novice teachers in seeing and learning from their own practice, and builds a mindset of continuous improvement about teaching practices that matter most for student learning.
	2. Timely—or in-the-moment—feedback allows novice teachers to improve their instructional decision-making and to adjust their practices in time to meet their current students’ needs.
	3. Students are an essential source of feedback for teaching and instruction, and all teachers should be supported and trained in listening to and learning from their students in formal and informal ways.
	4. Feedback is more likely to be taken up when it is provided by a trusted colleague or mentor who has in-depth knowledge of the local context.

Commitment Eight	<i>Principles</i>
We commit to practices and programs that are evidence-based and to seeking continuous improvement.	1. Both the teaching and learning for young people and the education of future teachers need to be rooted in practice and in research on practice.
	2. Evidence-based practices are, by their nature, not fixed and entrenched, but rather responsive, informed, and flexible.
	3. Programming is not offered for the convenience of researchers or external partners; instead, programming must align with the needs of the students and the school, meet the goals of the Teaching School, and advance the commitment to inquiry-based, anti-racist teaching and learning.

Commitment Nine	<i>Principles</i>
We commit to building communities-of-practice in which teachers learn and practice with each other and simultaneously focus on the	1. Teaching and teacher education is a collaborative endeavor and necessitates a professional culture where even the veteran teachers have a learner’s mindset and teachers welcome one another into each other’s classrooms.
	2. Learning to teach is an apprenticeship; experts need to make teaching moves and decisions explicit and visible.
	3. The expertise of experienced educators is an essential resource

development of children and teachers.	in the preparation of new teachers.
	4. The relationship between experienced and novice educators should be reciprocal: both are learners and teachers.

Table 4-2 Teaching School Commitments and Principles, 2/11/21

The Teaching School Model as Departure from Traditional Teacher Education

TTS model of educator preparation is designed as a departure from traditional models of teacher education wherein a beginning teacher’s relationship with the university effectively diminishes upon graduation and employment as a teacher of record. In such traditional models, the beginning teacher is left to navigate new contexts, colleagues, and full-time teaching responsibilities largely on their own. As previously discussed in Chapter 1, Figure 4-3 (below) demonstrates the traditional trajectory of a pre-service teacher to beginning teacher of record across two often-separated contexts: the university and the K-12 school setting. In such contexts, the university is often charged with the primary goal of supporting teacher learning, while the K-12 setting is primarily concerned with student learning outcomes, understandably so. However, when such separation occurs, pre-service teachers are left to navigate sometimes opposing contexts largely on their own (e.g., Bain & Moje, 2012), reducing the potential for meaningful connections between theory and practice, often learned and observed in university and K-12 school settings, respectively.

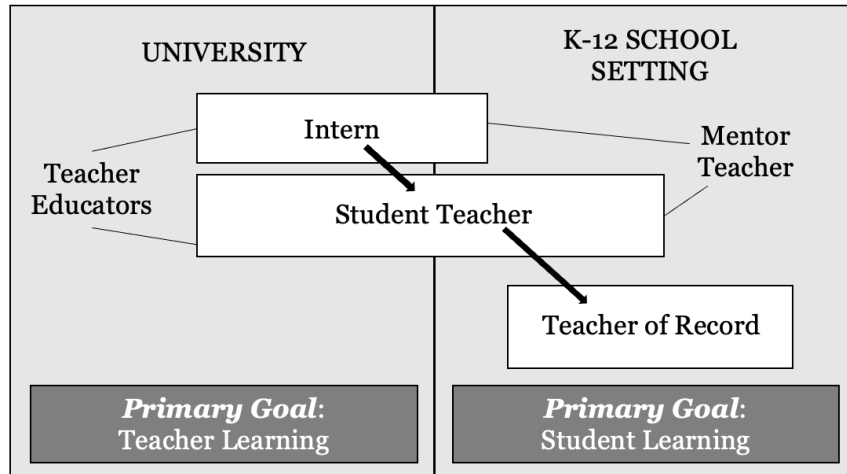


Figure 4-3 Traditional teacher education model

In response to such contextual and theoretical disconnects, TTS model attempts to bridge a divide between the university and K-12 school setting during both the pre-service and beginning in-service years of teaching. In Figure 4-4 below, I return to TTS model introduced in Chapter 2 to further illuminate its features in relation to this study.

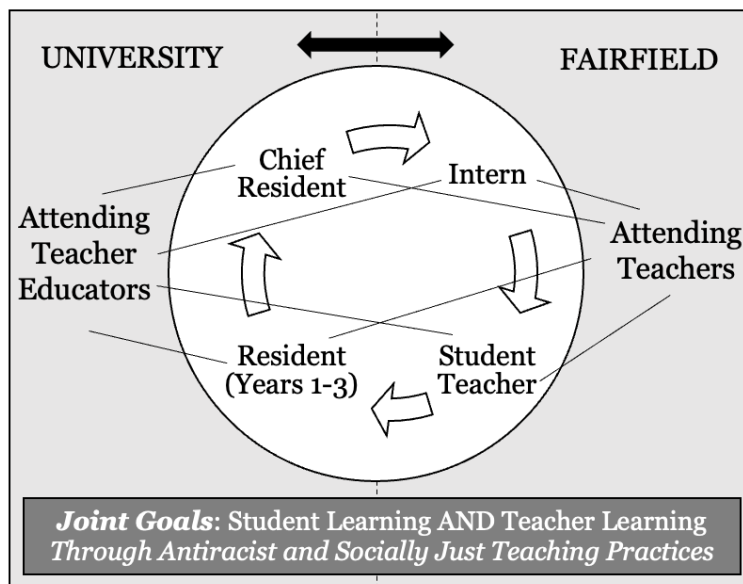


Figure 4-4 The Teaching School model

TTS model supports pre-service through beginning in-service teachers at different generational points throughout their development. Each phase (i.e., intern → student teacher → resident, etc.)

is considered a generation within the model, thus potentiating meaningful intergenerational learning with near peers as interactions between generations take place. Although such interactions could occur in traditional education models, such opportunities are not necessarily systematically built into pre-service or beginning teachers' experiences. Within TTS model, however, intergenerational interaction and near peer support is embedded within opportunities, such as residency support meetings, co-observations, and regular check-ins with attendings. Borrowing language from medical education, attendings serve as support for residents as they navigate and implement full-time professional responsibilities. Just as a medical resident performs critical patient care under the guise and support of medical attendings, teaching residents carry out meaningful instruction with students while receiving support from attending teachers and attending teacher educators.

Embedded, Extended, and Place-Based Teacher Education

TTS model supports pre-service and beginning teachers through an extended, embedded, and place-based framework (Figure 4-5, below). First, and as aforementioned, TTS model is designed to provide extended support to beginning teachers beyond the traditional one to two years typically received in undergraduate or graduate teacher education. Instead, TTS extends university supports in the form of attending teacher educators into the first three years as a teacher of record. During this time, teaching residents receive support through observational feedback, pedagogical coaching, co-planning, and opportunities to meet in intergenerational teams to analyze and discuss problems of practice specific to the Fairfield context. In addition to extended supports, university supports are embedded within the Fairfield context in the form of on-site coaching and, in some cases, university coursework. Although not all courses TTS participants take are currently located at Fairfield, the project team has started to design

Fairfield-based offerings of university courses that would have typically been offered on the university campus. For example, team members and attending teachers have offered multiple iterations of a field seminar for mathematics interns and student teachers at Fairfield. In traditional models, interns and student teachers travel from their field placement to the university to engage in coursework. Within TTS model, increasingly more coursework will become available to participants over time, further diminishing the divide between university and K-12 school setting. For residents, all support from attending teacher educators takes place within Fairfield. One caveat to this embedded support is the virtual nature of the 2020-2021 school year, where all TTS participants conducted their teaching and training from a distance. In this case, attending teacher educators embedded themselves within residents' virtual classrooms, though there was no physical manifestation of embeddedness during the year of data collection.

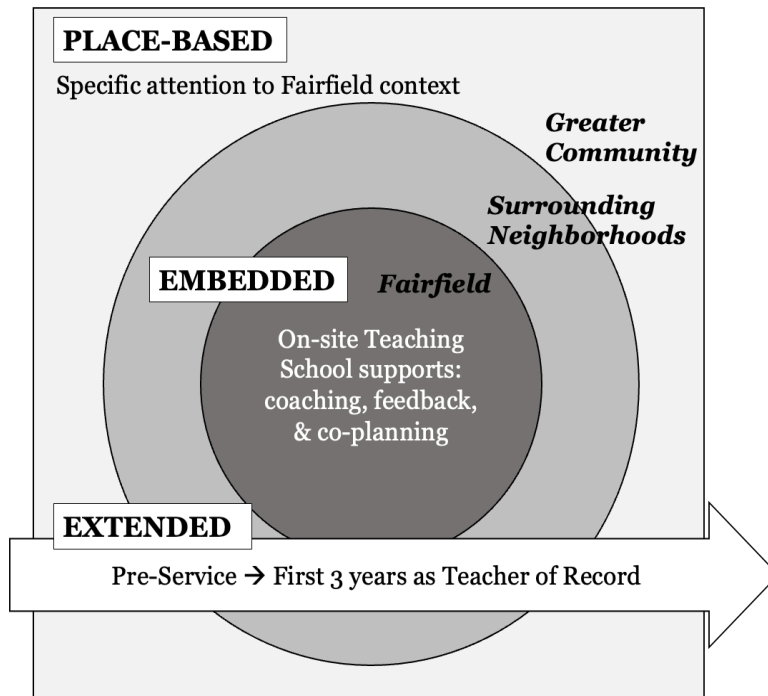


Figure 4-5 Embedded, extended, and place-based teacher education

Lastly, TTS is a place-based model of teacher education. All supports and opportunities to learn are centered around the Fairfield context, paying specific attention to Fairfield students and their interests, identities, and academic needs. Just as Fairfield's goal is to embed youth learning in inquiries that are embedded in local places of meaning to them, so is TTS's goal to embed teacher learning in place. In traditional models of teacher education, it can become difficult to center all problems of practice around one specific context and group of students when student teachers are placed in myriad field placements across different contexts. Although the traditional model has its advantages in exposing pre-service teachers to different views of teaching and learning, it does not support ongoing efforts to become more knowledgeable about one's own students and support their individual and specific needs. However, within TTS model place-based teacher education is a natural extension of embedded and extended supports. Because supports are embedded and take place within the school over a prolonged period, it is only natural that specific attention be placed on the school community and the surrounding context. This requires student teachers, residents, attending teachers, and attending teacher educators to build meaningful relationships with students, colleagues, and community members over time, made increasingly possible through embedded, extended, and place-based features of the model.

Teaching School Build Out Over Time

At the time of the study, Fairfield was in its second year of operation, with ninth and tenth grade running fully online in a virtual format. Due to the ongoing COVID-19 pandemic, teachers at the school enacted instruction, met with attending teachers and attending teacher educators, were evaluated by their administrators, and participated in staff meetings and professional developments virtually. Table 3-3 (below) details the build out of TTS, including the grades offered each year, the number of residents in relation to the total number of teachers at

the school, the number of interns and student teachers, and student enrollment. The shaded column (Academic Year 2020-2021) indicates the year of data collection. The asterisk in the 2022-2023 column for “Residents out of Total Teachers” indicates there is one Chief of Residents amongst the staff, as one resident completed the three-year residency during the 2021-2022 academic year and transitioned into the Chief of Residents position. In this new role, the Chief of Residents works closely with residents, student teachers, and attendings to support the development of practice, yet they no longer receive individualized coaching and attend residency support meetings regularly, although they may choose to as their schedule allows. This role is meant to allow for more leadership within the residency program, as well as more flexibility to engage in supports as needed.

	Academic Year			
	2019-2020	2020-2021	2021-2022	2022-2023
<i>Grades</i>	9 th	9 th , 10 th	9 th , 10 th , 11 th	K, 1 st , 2 nd , 9 th , 10 th , 11 th , 12 th
<i>Residents out of Total Teachers</i>	1 out of 6	2 out of 12	3 out of 18	8 out of 22*
<i>Interns/Student Teachers</i>	14	3	4	6
<i>Student Enrollment</i>	114	210	279	474

Table 4-3 The Teaching School build out over time

Perceptions of School Culture

I now turn to a discussion of the ways in which participants engaged in and perceived school culture within TTS. Drawing on interview data, I explore how TTS participants talked about their experiences with others, particularly as it relates to features that support or constrain the development of ARSJ STEM teaching practices. Throughout the subsequent paragraphs I work to make connections between participants’ perceptions and the specific ARSJ STEM practices highlighted amongst interactions across the staff. Because staff and school community

members represent both STEM and non-STEM educators, I do analyze participants' perceptions of the school culture as a whole, which has the potential to impact their development as educators in the school space. However, I also attempt to focus specifically on participants' perceptions of interactions with other STEM educators to highlight disciplinary-specific practices and foreshadow the potential to use such findings towards programmatic implications.

(Un)common Language: “What is the ‘it’ that we’re fighting for?”

Members of TTS community, which included student teachers, residents, teachers, attending teachers, attending teacher educators, support staff and administrators, were committed to antiracism and social justice. Both residents and student teachers expressed commitments to social justice and antiracism when interviewing to join TTS (a focus within hiring interviews), and their efforts to incorporate such themes into their practice will be discussed throughout the subsequent findings chapters. Such a commitment was further made apparent through the electives teachers designed for students, such as Black feminist thought, children in peril, and global issues, as well as how the school made space to celebrate Black history month, pride month, and participated in protests raising awareness around Black Lives Matter issues. However, not only did the methods by which to achieve elements of ARSJ teaching practice vary by individual at FHS, but it became clear based on interview data that—unsurprisingly—the school community was operating under differing definitions of antiracism and social justice, as well as focusing their efforts on varying segments of ARSJ teaching practice. As Stella described:

We're really pushing the boundaries and fighting and I'm like, but in what direction, because I don't think we've defined that. **What is the “it” that we're all**

fighting for? I think everybody you asked would give you a different response

(Interview, 2/16/21, emphasis added).

The “we” Stella is referring to here is inclusive of FHS teachers, staff, and administrators. She viewed herself as part of that team, choosing to use the collective “we,” yet it appeared that the end goal or the “it” they were all working towards was ill-defined across those within the school. Stella pointed out that teachers and administrators were fighting for something, but what that was exactly was dependent upon the individual. Emphasizing this thought, Kendall wrote, “many teachers believe that they teach for and about social justice, although **there is no consensus around what that means or what that looks like**” (Journal Entry, 4/13/21, emphasis added). For example, Kendall pointed out that Kira, her attending teacher from the previous year, and Matthew, Aaron and Iris’s attending teacher, “had a lot of bashing heads because of differences in grading and **differences in what it means to do social justice**” (Interview, 10/20/20, emphasis added). Although such data points suggest that participants experienced misalignment amongst the staff on what it meant to carry out elements of ARSJ STEM teaching in practice, misalignment in and of itself was not inherently counterproductive. However, given the backdrop of administrative turnover and online learning constraints, participants experienced few opportunities to collectively think critically about how to engage in ARSJ STEM teaching practices across the school. In the sections that follow, I explore participants’ perceptions of school culture through opportunities to collaborate and instances of misalignment.

Potential for Collaboration and Alignment

Throughout the year, Stella spoke about the lack of common language around ARSJ teaching practices within the school culture. As one of the founding teachers at FHS, and its first teaching resident, Stella had the opportunity to take part in “the creation of a lot of the values and

other things that we self-determined as a school” (Interview, 11/2/20). However, as the inaugural year progressed from the fall of 2019 to the winter of 2020, the school faced challenges such as administrative turnover and transitions to and from virtual schooling. Thus, collective ARSJ vision-setting sessions became few and far between. As Stella pointed out:

I feel like individually, most of us at [FHS] are doing that work in our best estimation, but **there's not a lot of collaboration across**. I also think as a school that's centered around social justice, it's important for us to norm and establish what that means to us. I don't even know that we're operating off a clear definition of social justice together, even though we probably set one at some point (Interview, 11/2/20, emphasis added).

Stella mentioned that teachers were enacting ARSJ teaching practice to their *best estimation*, although this could look different for different colleagues. In stating this, Stella affirmed her faith in her colleagues' work, choosing to view their stances from an asset-based approach. This subtle use of language is important because it showed that Stella was willing to work with others and not freeze her colleagues in space and time if they did not necessarily agree with her. Thus, even though teachers thought about social justice differently, their commitment was apparent to Stella. She even pointed out that as a first-year teacher the year prior, she did not always view her colleagues through an asset-based lens, and she stated that she once prescribed to “a level of arrogance that comes from being a new teacher” and perhaps did not take the time to “actually understand why people are making the decisions they're making.” Instead, she now saw labeling another teacher's practice “just or unjust” as “unhelpful” in learning the complexities of ARSJ teaching practice. Further, she said it is important to, “recognize the positive intent of the choices that people are making” and that it is “much more interesting to have actual conversations of,

this is actually a really hard balance to find, how do we figure out how to do that?” (Interview, 6/29/21).

Throughout her time in TTS, Stella made a point to collaborate and build relationships across disciplinary boundaries to learn more about ARSJ teaching practice. This was made apparent by how she spoke about the value in viewing all her colleagues as important sources for learning. Stella came to view learning from her colleagues with differing views as “so important,” describing two teachers on the ninth-grade team as “very experienced and seasoned educators, who have been engaging with socially just and antiracist teaching for a very long time” (Interview, 6/29/21), even if that teaching differed from her own approach. Given these stances, Stella was able to work with and educate colleagues around school social justice concerns, such as the use of students’ preferred pronouns. At a celebration for Stella’s completion of the residency program in the spring of 2022, many of her colleagues praised her ability to teach them about social justice issues without making them feel small. One colleague pointed out that prior to working with Stella, he did not know about the importance of using someone’s preferred pronouns and he was grateful for the opportunity to learn from Stella and her patience in kindly correcting him over time (Reflective Field Notes, 6/21/22). Furthermore, as Stella recently moved into her fourth year as a teacher and Chief of Residents, she initiated a survey asking students about their preferred pronouns, which would then be communicated to staff (Figure 4-6, below), thus demonstrating Stella’s continued commitment to building a socially just school environment for all students through collaboration with colleagues.



Figure 4-6 Names and pronoun form, school artifact, 9/27/22

It is important to note that Stella’s opportunities to engage with her colleagues around issues of ARSJ teaching were not TTS-designed structures, such as professional development, staff meetings or intentionally designed common prep periods. Rather, Stella sought out colleagues on her own for purposes of co-planning, informal conversations about ARSJ approaches to practice, and ongoing conversations about social justice issues such as student pronoun use. And although Stella viewed her colleagues as critical sources for learning, this did not manifest in all teacher-teacher relationships. To this end, Aaron reflected on his experience in staff meetings, describing it as a space where differences in how teachers thought about ARSJ STEM teaching practices were illuminated:

There were a lot of times where we would have a staff meeting, and then they would talk about, for example, grading being a thing where you shouldn't give students a zero if they don't turn in the assignment, and there were a few teachers that were like, ‘oh that works for my students, I’m going to keep doing that.’ And then [Matthew] was like, ‘oh I have the research up right in front of me that says

that that does not work for students, we should stop doing that.’ **So, I feel like those disconnects in terms of, if you're a social justice school and there's these social justice or equity grading practices, then I feel like they really should be universal.** But then there's this whole other thing of teacher autonomy in terms of just like, I want to do what I want to do. But it's just like at the end of the day, if you're here for your students and this thing promotes equity in grading then why wouldn't you want to do that? (Interview, 4/27/21, emphasis added)

In the above excerpt, Aaron’s observations highlight the theme of uncommon language and perception around ARSJ STEM teaching practice. In what he described, there appeared to be a disconnect between teachers’ current practices and *his perception* of equitable grading practices, as informed by Matthew’s mathematics teaching practice and perception of mastery grading. Although Aaron puzzled over the question of why all teachers in the school did not want to adopt mastery grading practices to promote equity, evidence does not suggest that other FHS teachers wished to make their grading practices inequitable. On the contrary, data indicate that FHS teachers shared a commitment to ARSJ STEM practices, even if their definitions or conceptions of how to get there varied. For example, one STEM teacher’s approach to grading appeared to be tied to content coverage, which she viewed as an important and critical element of equitable educational experiences for students. In what appeared to be efforts to reduce stress for both teachers and students in the middle of an online school year, the district superintendent sent out a statement outlining a new policy wherein “teachers [were] required to limit graded assignments to up to two per subject per week” (Personal Communication, 2/7/21). In response, this teacher designed a survey⁵ for students in which she expressed feelings of frustration and elicited student

⁵ Unfortunately, I cannot share the actual survey here. Even though survey data came from interactions with Kendall, I do not have the survey author’s permission to do so.

feedback for actionable next steps. In the survey, the teacher described the decree as something that would put students further behind in terms of content coverage, thereby connecting traditionally graded assignments with equitable learning experiences for youth. Although STEM concept and skill learning is the basis for all ARSJ STEM teaching practices, connecting STEM concepts and skills with more responsive and holistic assessment and evaluation measures could have further connected this teacher's practice with that of her STEM colleagues and elements of ARSJ STEM teaching practices.

Comparing data points around Matthew's and other teachers' views on grading appears to surface differences in not only how they approached grading and assessment, but also how they perceived ARSJ STEM teaching as a whole. For Matthew, it appeared as though his approach to grading was in service of socially just teaching as transformation, which appeared to be in efforts to *design responsive evaluation and assessment measures*. He did not wish to continue status quo grading practices. Instead, he wished to transform how mastery was defined in his class, opting not to grant zeros, and allowing late work to be turned in until the last day of a semester. Contrastingly, other teachers in the school appeared to view access to disciplinary concepts and skills as tantamount to ARSJ teaching practice, which is a vital factor but cannot stand alone. Such differing views are not untenable, though they are not fully aligned. Because weekly staff meetings were typically used for "grade level teams to meet" (Principal Communication to Staff, 5/10/21) or for teachers to "use the time as you need to use it" (Principal Communication to Staff, 5/17/21), FHS staff did not engage in many opportunities to constructively share ideas around ARSJ teaching practices or use a working definition (as laid out in this dissertation) to design instructional opportunities and policies. Furthermore, the administration at the time turned down the university's offers to support teachers in this endeavor during staff meetings. Perhaps

with additional opportunities and scaffolding, differences in perspectives on ARSJ teaching practices could be explored, critically examined, and used to build a more robust understanding of what ARSJ teaching looks like in practice.

An additional factor in the perceived misalignment on approaches to practice I observed across the school community is the notion that teachers and staff arrived at FHS with varying backgrounds and familiarity with ARSJ teaching practice. During a meeting with student teachers, coaches, and school staff, Ms. Fay, an administrator, mentioned that she was “still trying to wrap [her] mind around what social justice means” (Field Notes, 1/22/21). Similarly, Mr. Nelson, another administrator, said he was “really interested in getting student teachers’ feedback” because he was still working on “systems and policies” that would be aligned with ARSJ values (Field Notes, 1/22/21). Thus, it appeared that school staff were aware of conceptual discrepancies in approaches to practice across colleagues, as well as areas for improvement. In that same meeting, however, Ms. Smith, the school principal at the time, said that “we agree this is how we do ARSJ” across the school, which seemed to be in opposition to evidence across other data sources. She did mention, however, that there was not a set of practices or training all teachers received in relation to ARSJ teaching practice, and “professional development is not where we need to be” (Field Notes, 1/22/21), perhaps alluding to the idea that more could be done to develop ARSJ teaching practices in the context of teacher professional development.

Perhaps if more opportunities for productive conversations were made available across FHS community members, teachers would be able to decompose and analyze practice through the lens of seven ARSJ STEM teaching practices against a backdrop of STEM concept and skill learning. Part of the disconnect between staff members could have been because each staff member was focusing on different aspects or different conceptions of ARSJ STEM teaching

within their practice. Up to this point, I have largely discussed ARSJ STEM teaching as a whole, which is how participants mainly talked about and interpreted their use. However, each staff member could have been focused on one or multiple, yet different, practices as one another, causing the perceived disconnect. For example, had Kira and Matthew aligned on their commitment towards STEM concept and skill learning, then perhaps a conversation could have ensued about practices they used that supported students' sensemaking. Although they did not align on measures of *assessment and evaluation* towards ARSJ aims, there could have been other areas of their practice where common ground could have been found. For example, Kira did not adopt the same grading practices as Matthew, yet her commitment to designing project-based units focused on the school and surrounding communities (e.g., air quality and environmental racism in the city) could have closely aligned with the ARSJ STEM teaching practice *Teacher draws on students' cultural knowledge and capital to plan and implement culturally sustaining STEM lessons*. These points of connection could be further emphasized given additional scaffolding and time to meet, though pandemic constraints did limit the amount of face-to-face time FHS staff members experienced.

Student Teachers and Attending Teachers: Instances of Misalignment

Lack of a common language around ARSJ STEM teaching practices led to not only “bashing heads,” as Kendall recalled earlier, and dissonance during staff meetings, but it also created varying experiences for student teachers and residents who worked alongside attending teachers. Expanding on the data exemplar explored above wherein Kira and Matthew appeared to have different perceptions of what it meant to be an ARSJ STEM teacher, I examine what stance on ARSJ teaching Kendall developed after spending a year of student teaching with Kira, her attending teacher during the previous 2019-2020 academic year. Based on my analysis, it

appeared that Kendall learned a great deal about teaching and learning from her attending teacher that translated to her stances and approaches to practice the following year, even if such opportunities presented varying perspectives of ARSJ STEM teaching practices.

Throughout her interviews, Kendall described Kira's approach to science teaching and learning as very different from her own:

[Kira] and I had very different ideas of what social justice means, or even just how do you be an activist and how do you support the causes that you care about, and I guess the way to navigate that in the system (Interview, 10/20/20, emphasis added).

Throughout the year of data collection, Kendall brought up multiple instances where she disagreed or actively resisted Kira's approach to ARSJ STEM teaching practices. For example, when discussing seating charts in a residency support meeting, Kendall reflected on how Kira presented her seating chart to Kendall: "when setting up a seating chart, Kira told Kendall that she puts the 'smart kids' in the front, so go to them if she has any questions" (Reflective Field Notes, 3/9/21). It is important to note here the nature of this data point as a secondary source. Although these words did not come directly from Kira, the data suggests that Kendall viewed Kira's stance on ARSJ STEM teaching as different from her own, and coming from a deficit-perspective, at least for those students who were not placed in the front of the class. By explaining the seating chart to Kendall, Kira does attempt to make the invisible work of teaching visible by making her reasoning accessible to her student teacher. However, it then became up to Kendall to determine whether this practice was aligned with ARSJ STEM teaching practices and if she should then take up such a practice in her own teaching. It could have been the case that

Kira was partly engaging in the practice of *positioning students as experts*, though it does not appear to extend to all students.

Although Kendall identified such a practice as misaligned with her perceptions of ARSJ STEM teaching practices, it was also not always clear that Kendall viewed her students from a wholly asset-based perspective. Perhaps because her student teaching experience did not provide her with extensive modeling on how to enact asset-based, ARSJ science teaching, some of these practices could have made their way into her repertoire and mindset. It also could have been the case that Kendall's existing ideas about students were simply confirmed or remained unchallenged throughout her student teaching experiences. In response to a journal prompt asking about current progress on pedagogical goals, Kendall wrote about a goal she set for herself at the beginning of the school year around having an asset-based mindset:

Have an asset-based mindset: **I believe I have done this to the best of my ability while also being realistic.** I think the best prediction of future behavior is past behavior, so I keep that in mind in terms of expectations for students. (Kendall, Journal Entry, 12/14/20, emphasis added).

In the excerpt above, Kendall mentioned that she exhibited an asset-based mindset as best she could, while also keeping in mind students' past behavior. This stance appeared to place the responsibility for Kendall's expectations of students in the hands of students; if they performed at or above her level of expectations, then she believed them to be capable of academic success, per her definition. On the contrary, if students did not perform at or above her level of expectation, then she might not believe them capable in the future. Such a stance not only places responsibility on the student, but it largely negates the role of the teacher. Furthermore, such a

stance becomes difficult to align with any element of ARSJ STEM teaching, though STEM concept and skill learning could remain a pedagogical goal, at least for part of the class.

In the excerpt that follows, Kendall articulated a complex view of students and her role in their learning, one that tries to avoid a deficit perspective but also excuses the teacher's role in student learning as she reminded herself to work on *not taking things personally*:

I think just **teachers in general, need to be reminded regularly to not have a deficit mindset of their students and to not take it personally**. My biggest thing is just don't take it personally, like your students are not out to get you, like **they are either doing their best or they're not doing their best, but there's a reason why, you know. It's not anything about you or what you're doing**, which I know it's hard to hear (Interview, 10/20/20, emphasis added).

The above sentiment highlights Kendall's views of students through a fixed mindset and further removes herself from potential agency as a science teacher. While Kendall recognized the importance of not having a deficit mindset, at the same time she mentioned that students will either do their best or not, essentially leaving little room for student growth and with no responsibility for such actions placed on the teacher. Such an abdication of educational responsibility points to her stance on teacher learning through a fixed perspective, which could also have potentially influenced her resistance to feedback and iteration on her practice, which will be explored in the following chapters. Furthermore, Kendall's interview data related to curricular adaptation complicates this view in that she was saying the "right" things. When speaking about the curriculum, Kendall identified areas of growth, wishing for it to be more "place-based" and "representative" of students' identities and interests (Interview, 2/4/21), going so far as to say she should "analyz[e] the curriculum and just be critical of the curriculum, not

expecting that just because I was given this means that it's good and that it's inclusive and will work for my students” (Interview, 2/4/21). Such sentiments align closely with ARSJ STEM teaching practices of *critically examining and adapting STEM curricular materials*, as well as *drawing on students’ cultural knowledge and capital to design and implement culturally sustaining STEM lessons*. However, her critique appears to be largely pointed to the curriculum materials and designers, not necessarily her role in adapting and presenting material to students, thus further separating herself from responsibility as the teacher and maintaining a fixed mindset when it came to teacher growth. Furthermore, although Kendall talked about her wishes for curricular adaptation, her enactment of such views in the science classroom appeared to leave room for improvement. Such findings, as will be explored in subsequent chapters, point to the importance of not only understanding participants’ views in hiring interviews and the like, but also how such views become animated through practical implementation and curricular design tasks.

As a first-year teacher espousing such views, Kendall’s reflection on her student teaching experience with Kira could have contributed to her stances on teacher learning, although I do not intend to draw a direct correlation between Kendall’s student teaching experience and her tendency to view students, or teachers, through a fixed or deficit perspective. Yet, such an experience in the 2019-2020 school year could have set the foundation for Kendall’s approach to student and teacher learning during the following virtual school year (2020-2021). For example, in the second semester of her student teaching, Kendall and Kira were asked to support three first-semester interns who would visit 1-2 times per week for observations, with the intention of building an intergenerational team and fostering near-peer engagement. Both Kira and Kendall were resistant to this structure and this view was supported by Kendall’s field instructor. In

response, the field instructor sent me an email outlining his concerns for Kendall's learning, in which he stated, "which is primary, the student teaching experience of Kendall or the observation experience of the interns?" (Email Communication, 1/15/20). Such data suggests that Kendall engaged with support systems during her pre-service year that preferred a "closed-door" or fixed perspective when it came to teacher learning, perhaps viewing the development of teaching as a linear and an autonomous task. While not diminishing logistical concerns and potential added stress on Kendall, both student teacher and intern experiences could have been viewed as primary goals in this space, which could have served as a model for how Kendall approached teacher learning during both her pre-service and first years as a teacher of record.

Fairfield High School and the University: Working Towards Common Practice within The Teaching School

In addition to working towards alignment amongst FHS teachers and staff when it came to perceptions of ARSJ STEM teaching practices, there were also instances of participants' perceived misalignment between the school and the university. As previously stated, TTS model was meant to draw stronger and more meaningful connections between the university and the K-12 school space for pre-service and beginning in-service educators in learning to teach STEM in ARSJ ways. In the following sections, I explore the ways in which participants perceived the model as aligning university and FHS experiences, as well as the ways in which such alignment could be improved towards more common understanding and enactment of ARSJ STEM teaching practices.

Navigating University and FHS Contexts

Prior to its fall 2019 opening, it appeared that teachers, staff, and university personnel had varying visions of what FHS could or should look like. To add additional context, the school

faced numerous administrative turnovers throughout the first two years of operation, which led to increased challenges in building a unified school community around common ARSJ STEM teaching practices amongst teachers. By the time data collection had concluded in the summer of 2021, the school had seen four different principals over the course of two years, with an additional new principal starting in the spring of 2022. Such turnover, combined with transitions to and from virtual learning imposed by the pandemic, created many challenges in arriving at common perceptions of practice across teachers and partners. As Stella stated, because of “all the hurdles the school has gone through, a lot of things get pushed to the side” (Interview, 11/2/20). At the same time, university personnel remained largely consistent, and initial vision-setting around teacher and student learning through ARSJ teaching practices continued to focus on the idea of a community school centered on social justice through project-based learning and engineering design (Field Notes, 10/28/20). Such ideas were shared and developed with school leaders and district personnel. Nevertheless, student teachers and residents expressed perceived differences between the school and the university’s visions for TTS. For example, Kendall spoke about her experience navigating between how each institution, FHS and the university, as well as how FHS teachers spoke about TTS:

I got into this a bit last year with hearing more about, you know, what teachers were brought into the Teaching School and hearing about what was the University’s vision versus what was maybe more of [the principal’s] vision for the school. And especially hearing a lot more from Kira about her definition of social justice and her, you know, what did she come to the school for. So, **I learned a lot more from her about how she thought this school was supposed to be the best of the best and this was supposed to be like the best students in [the city].**

Which is, of course, not what I was told from [University faculty] when I was brought in. I was told this is going to be a community school and that most of the students were from the neighborhood. And that we were talking about social justice and that we were doing project-based learning, and that we were engineering design focused (Kendall, Interview, 10/20/20, emphasis added).

Based on Kendall's above reflection, it appeared as though teachers entered TTS either being told different visions for the school or they arrived with preconceived notions of what TTS should be. Part of this could be attributed to communication, becoming more and more difficult as administrative turnover and transitions to virtual schooling occurred simultaneously, and part of this could be attributed to teachers' personal stances on ARSJ STEM teaching practices. As Kendall pointed out, Kira was under the impression that FHS was meant to be *the best of the best*. This could have come from communication with the founding principal, or it could be how Kira viewed the embodiment of ARSJ STEM teaching practice. Contrastingly, university faculty communicated their vision of the school to Kendall, which differed from that of her attending teacher. Similarly, Aaron spoke about the ways in which he saw differences in how Matthew, his attending teacher, viewed the school as a community school and perhaps where the school was at the time:

There was a lot of disconnect between what the school, at least this is coming from Matthew's perspective, like what the school advertises itself as or what it wanted to be versus what it was actually doing to get there, and navigating that was kind of difficult (Interview, 4/27/21).

In the above excerpt, Aaron described a disconnect between Matthew's vision for the school and what it was in practice during the 2020-2021 school year. Examples of such disconnects include,

“grading, you know, how has that been unjust in the past, how has that been racist in the past, or dress codes, or policies on behavior” (Stella, Interview, 2/16/21), which largely came from district policy and practices. Aaron and Stella’s perspectives attend to TTS’s commitment to “preparing educators to work for the public good, and within the realities of an existing public school system,” specifically tied to the principle: “TTS, embedded in a public school system, **prepares teachers for navigating—and, when necessary, challenging—larger systems of schooling in order to better serve students and families**” (TTS Commitments and Principles, 2/11/21, emphasis added). Although TTS was designed to take place within a new school, the school was formed within the context of a large city school district with long-held beliefs, values, and practices. TTS recognizes that its ideally designed structures do not exist in a vacuum and works to support teachers to advocate for themselves and students to change practice and policy towards more ARSJ aims. Currently, the school has abolished its dress code and is moving towards a more restorative approach to discipline rather than more traditional punitive measures that do little to improve student learning outcomes. Such changes indicate FHS’s attempts to navigate district policy in service of building a more ARSJ educational environment for all students.

In addition to differences in perception or stances on ARSJ STEM teaching practices, Aaron pointed out the ways in which he experienced differences in FHS and university visions during his time as an intern and then student teacher:

I know before we started [at FHS], winter 2020, even then when Brooke came to talk to us, [she] did kind of promote it as like this social justice, like project-based, forward thinking progressive school. **And maybe more emphasis on the fact that, it's new and it's still developing, and teachers are still trying to**

figure out like what those things kind of look like. Maybe that would have been beneficial, like maybe they did kind of mention it, and I just forgot about it, but maybe that affected, like my overall perception of the school once I got there (Aaron, Interview, 4/27/21, emphasis added).

Aaron's above insights point out that although university personnel promoted a social justice and project-based school, the school was still in its infancy, and he would have appreciated transparency in this regard. Simply put, starting a school is difficult and is not without growing pains. This does not mean that TTS and FHS are not centered on social justice and meaningful project-based units. However, as Aaron pointed out, it could mean that such facets were not fully formed within the school's first two years, a particularly challenging feat given the previously stated circumstances of administrative turnover and pandemic constraints.

Despite challenges to align ideal TTS and FHS practice within the context of a large city school district, efforts to align supports for TTS participants across university and FHS contexts did take place throughout the 2020-2021 school year. For example, the university held monthly seminars for student teachers across disciplines to come together and discuss problems of practice related to their experiences at FHS. Aaron and Iris were included in these meetings, as well as an additional social studies student teacher. Such opportunities were important for student teachers, particularly as they stated it was challenging to apply what they learned in university coursework because it was not focused on the FHS context. For example, Iris stated that learning from her peers in different contexts was not particularly helpful for her experience at FHS:

Our classes are coming with lots of different perspectives from other schools, **but being able to specifically reflect upon, you know, [FHS] and the teaching**

styles that we've seen there, it was sometimes hard or even more so like to take the lessons that we learned in class and actually apply them. Sometimes it's difficult because I guess [university classes] were very much generalized. Like the general takeaways for the most part were able to be applied, but I'd say that was probably one of the biggest difficulties (Interview, 4/20/21, emphasis added).

Within the seminar space, student teachers were able to talk about how ARSJ presented itself within their experiences with their attending teachers, as well as how their views of ARSJ STEM teaching practices had evolved over time. Furthermore, student teachers had the opportunity to meet with FHS administrators, university faculty, and residents at different points throughout the seminars.

However, opportunities for intergenerational learning between student teachers and residents could have been further developed. Within Kendall's data, I noticed a theme of a desire for more intergenerational structures during the 2020-2021 school year. Although I did not notice the same patterns with student teachers or in Stella's data, these data shed light on the ways in which Kendall wished to be supported and her desire to engage in a stronger community of practice during the virtual year of instruction. Additionally, these findings suggest structures that were missing from TTS model that would perhaps work to better align university and FHS learning contexts for participants. In the excerpt below, Kendall voiced her desire for more connections between residents and student teachers:

I would love to have more connections with the student teachers... to be able to also support them because student teaching is also really hard...and I think in being a teaching intern or student teacher, you often forget that, like, there's other ways to do things. Right, you can either know like, oh, I kind of

liked that, or like I didn't like that, but it's really hard to say like, I feel meh about that. You know, like I feel like it could be better, but I don't quite know the way. So, I think just being able to have more experiences, more conversations. **I loved last year when I got to observe other people, but I wish that that was like more a part of the model is that you do observe different people and you do just have these conversations**, like even if it's just a once a week or once every two weeks lunch meeting of just like how are things going, what things do you have questions about? (Interview, 10/20/20, emphasis added)

One way to approach the excerpt above is to consider how Kendall wished to be a support system for student teachers. She mentioned that her own student teaching experience was difficult, and she wanted student teachers to be aware that there is not one singular way to approach teaching and learning. It appears Kendall was yearning for a community where she felt she could contribute as a new resident who had once been in the student teachers' place, which is interesting given data related to her stances on teacher learning discussed thus far. Kendall was perhaps projecting her own student teaching experience onto student teachers during the 2020-2021 school year, as she clearly expressed the idea that student teachers needed to learn about multiple perspectives on teaching and learning for social justice. Furthermore, Kendall mentioned that she wished additional observation outside of her attending teacher could be part of the model. Kendall makes an important suggestion here, and this is a significant consideration in building a strong network of intergenerational learning opportunities as TTS continues to grow over time. It is also important to note that there were TTS conceptual/content and structural features designed to attend to Kendall's concerns: 1) participation in grand rounds, where pre-service teachers would have the opportunity to rotate between attending teachers based on

mentors' pedagogical strengths, and 2) development of a community of practice and community building/understanding. However, distance learning due to the COVID-19 pandemic adversely affected the ability to engage in such features throughout the 2020-2021 virtual school year. Nevertheless, analysis of Kendall's remarks only further highlights the need to continue developing and engaging in such opportunities in the future.

Successes and Challenges in Building Intergenerational Learning Structures During an Online School Year

In addition to navigating university and FHS contexts within TTS, student teachers and residents were asked to navigate learning to teach and developing their emerging ARSJ STEM teaching practice within a virtual school culture. Because the entirety of the 2020-2021 school year was conducted online, student teachers and residents experienced both challenges and successes in developing their ARSJ STEM teaching practices. Up to this point, I have treated the virtual school year as a contextual factor in participants' TTS experiences. In the sections that follow, I bring the constraints and affordances of a virtual school year to the forefront, exploring participants' challenges and successes in learning to teach fully online.

Challenges to Developing ARSJ STEM Teaching in an Online School Year

Both student teachers and residents experienced challenges in learning to teach during an online school year. Specifically, participants described difficulties in both observing and carrying out ARSJ STEM teaching in ideal ways. For example, Kendall spoke about issues of power in her virtual classroom that she felt were unique to the online school year:

I think there's such a big part of power. **I think it's really hard to give students as much power in this setting.** Right? I'm the one who starts, I'm the one who runs the meeting and I'm the one who puts up the slide and I'm the one that says

what we're doing when and how it goes. And, you know, I'm the one who says when your conversation's done, and I wish all of that wasn't true. **I wish that it got to be more of a conversation. But because of the way it is set up, it's really hard to give students voice in a way that they want to give it. It's all on my terms** (Interview, 10/20/20, emphasis added).

In the excerpt above, Kendall voiced a desire to have more of a conversational feel to the class yet felt that this was difficult because it was *all on her terms*. Kendall's desire to shift the power dynamic in her classroom is a potential starting point in developing and enacting the ARSJ STEM teaching practice *Teacher positions students as experts in their culture and agentic changemakers*. Bending the scales of power is something Kendall highlighted as important in carrying out ARSJ STEM teaching practices, although balancing power in the virtual setting became more difficult because class sessions were typically more teacher centric. In the virtual setting, students rarely turned on their cameras or made use of their microphones to participate in class, something that both Kendall and Stella chose not to enforce because they felt strongly about giving students choice in the matter to maintain a socially just classroom environment. However, what Kendall described above (*I'm the one that says what we're doing when and how it goes*) could also be reminiscent of in-person teaching and learning. In an in-person environment, the teacher typically plans for instruction and facilitates transitions between activities. Thus, although she spoke about challenges as uniquely tied to distance learning, it would be interesting to see how Kendall's ideas about power played out in an in-person classroom, though I was not able to attend her class before she ultimately left the school in the fall of 2021.

In addition to issues of power, Kendall described her feelings around learning to teach online as “almost doing a different practice.” Although she felt she was gaining experience as a teacher, “it still looks like I’m working towards something different than I would be doing in person” and her development “feels like a little bit of a pause” (Interview, 2/4/21). Specifically, Kendall spoke about her interactions with students and worries about how to approach situations with off-task conversations in the classroom. In the online school year, Kendall did have to manage students’ conversations in the chat, though she did not truly experience student dynamics in the same way she would have in an in-person setting. As Kendall pointed out:

Something huge **I want to work on is not letting kids upset me**, to be honest. I really want to work on not saying something in the moment and then regretting it, which I’ve done like couple of times online, but it just doesn't happen as much online because you just can't hear the kids. So, I think a big thing of getting used to being in person is hearing those group talks and **it’s all of the stuff that’s not the content**, it's all of the stuff of hearing kids did this to another kid, how do I come into this situation? How do I react to that situation? What do I do if the kid is harming themselves or others, I guess with their words or something? What is our protocol? Do I keep them after class and talk to them? Yes, but like what if it keeps happening? **So, with all of these interactions, things that are not, we don't see online.** That's a huge thing for me (Kendall, Interview, 2/4/21, emphasis added).

Again, Kendall brought up the idea of not taking things personally or letting students upset her, something she was working on throughout the school year. In thinking through this, she had many questions about how to approach students’ conversations that are not about the content.

She mentioned that she did not see this online, but she expressed worry about how to handle these situations in person. This excerpt highlights the need to support Kendall in not only shaping her classroom management towards ARSJ aims, but also shifting her perspective a bit to become more asset-based when considering students' off-task conversations. First, it is important to consider, what does she mean by "all of the stuff that's not the content"? Is there room for students to talk about tangential topics that come to mind as they engage in disciplinary work that can then be incorporated into her planning and instruction? Such a perspective could have supported Kendall in *drawing on students' cultural knowledge and capital to plan and implement culturally sustaining science lessons*. Or did Kendall expect students to use only the words and ideas she presents to them in class? In which case, Kendall does not appear to articulate a shifting of the power dynamics that she worried about online and that ARSJ STEM teaching practices would indicate. Kendall also asked about the school's protocol, which connects to the school's culture when it comes to discipline. Are there restorative practices and policies put in place that would shape the nature of Kendall's conversations with students? Why was Kendall unaware of those practices? Was the distance learning necessitated by the pandemic responsible for a lack of communication about school-wide management practices? Regardless, what does this mean for how TTS should support Kendall, and other TTS participants, in fostering restorative conversations with students on their own? How should university-based TTS staff navigate questions of school culture that are not fully in their purview?

The excerpt above also highlights the isolation in which Kendall was operating within the virtual school culture, emphasizing the difficulties in building and enacting TTS-intended features, such as seminars and case conferences around problems of practice with colleagues. Similarly, Stella pointed out that "it's been harder to have those learning communities"

(Interview, 6/29/21) with colleagues throughout the virtual school year unless teachers were seeking out those relationships on their own, or if they had structures in place such as residency support meetings and meetings with attending teachers. For example, during the 2020-2021 school year, teachers and staff interfaced online during weekly staff meetings, yet the nature of these staff meetings made it difficult to build strong intergenerational relationships amongst colleagues. Ms. Smith, the school's principal, would often start the meetings with announcements and then the remainder of the time was used for either check-ins with grade level teams or individual work time, both of which were largely unstructured (Field Notes, 3/3/21). This unstructured time could be viewed in two ways. First, Ms. Smith was giving teachers and staff time to de-stress, plan for the next day's instruction, or to generally use how they see fit. This could have been an important consideration for a school leader during the virtual school year where teachers and staff were feeling the weight of the COVID-19 pandemic as it impacted their students and themselves. Secondly, it could also be viewed as time that could have been allocated for community building and vision-setting around ARSJ STEM teaching practices across school members. It is important to note that TTS staff did offer support through leading professional development during staff meetings and integrating ourselves more within teachers' classrooms. However, these offers were largely not taken up and district policy prevented TTS personnel from interacting directly with students and moving between virtual classrooms outside of teachers with whom they worked directly. Because TTS learning opportunities (e.g., coaching, seminars, co-planning) did not extend to the whole staff, residents' and student teachers' learning communities were confined to their specific place in TTS – residents with attending teacher educators, and student teachers with their respective attending teachers.

In terms of Stella's instruction, she also found it difficult to implement her project-based curriculum in ways that she might have in person due not only to virtual technology constraints, but also to the real impacts that the COVID-19 pandemic had on students' lives outside of the classroom:

Once a week I get a message from a child who is missing my class because they have to attend a funeral. Once a week from September to now, like there's probably very few weeks where that's not true (Interview, 2/16/21).

In response to the trauma students were experiencing outside of the classroom, Stella arranged her class time to focus on collaboration and rarely assigned homework unless it pertained to students' preparation for presentations: "There's a lot happening that I think it's unfair to ask of students' time outside of [class], and I think we can accomplish what we need to within the class space and also particularly for a project-based class" (Interview, 2/16/21). This adjustment was responsive to students' needs during the virtual school year and connects to the ARSJ STEM teaching practice of *evaluating and assessing students' STEM sensemaking through responsive measures*. Yet, such a change in content coverage potentially limited the amount of time and the ways in which students were developing disciplinary knowledge and skills. Despite such challenges, Stella was still able to facilitate the completion of three design cycles⁶ focused on students and the surrounding school community in an online environment, which supports students in *developing STEM tools to address community concerns*.

In addition to challenges of isolation and curricular adaptations, student teachers faced challenges of not only implementing, but also observing ARSJ mathematics teaching practices with their attending teacher. Prior to the move online in early March of 2020, Aaron and Iris

⁶ I present an explanation of the design cycle and its use in Stella's class in chapter 5.

were intern-teaching in Matthew’s classroom starting in January of 2020. During this time, Matthew was planning for a project where students would identify, analyze, and recreate geometric patterns they found in African works of art (Field Notes, 2/28/20), which is an example of Matthew *critiquing and adapting curricular materials*, as well as *developing disciplinary identities through representation and widened epistemic perspectives*.

Unfortunately, Aaron and Iris “saw the introduction, but never saw the follow through” for the project (Interview, 4/27/21). Constraints of the following virtual school year made it difficult to observe this kind of instruction. As Aaron pointed out: “Since it was online and kind of hard to get students engaged at all, a lot of the things that we did was really just learn content without really any tie to like the real world” (Interview, 4/27/21). Interestingly, when initially asked about how online learning impacted his opportunities to learn ARSJ mathematics teaching practices, Aaron responded:

I don't really feel like it's affected my ability to learn about antiracist teaching because I feel like a lot of that can just be done through conversations and at the end of the day, I don't really think it affected it that much (Interview, 4/27/21).

However, when pressed further to think about how it may have impacted his ability to observe instruction, he replied: “if we were in person and I got to see Matthew do more explicit social justice teaching or projects, that would have been nice” (Interview, 4/27/21).

Successes in Learning to Teach in an Online School Year

Although both residents and interns experienced many challenges in developing, observing, and implementing elements of ARSJ STEM teaching practices, there were also some bright spots that resulted from distance learning. Both Iris and Stella highlighted potential benefits to learning online, stating that it forced them to think about issues of equity and justice

in nuanced ways. As Iris pointed out: “COVID has brought out a lot of issues in terms of equity and accessibility. I think it has enhanced the opportunity to actually talk about it” (Interview, 4/20/21). Similarly, Stella stated: “The pandemic has, you know, exacerbated all of these issues that we already see, so they put them really front and center... and hopefully helped me center them in my practice, even when we're outside of this space” (Interview, 6/29/21).

In addition to highlighting issues of equity and justice, Iris also mentioned a unique benefit to learning to teach online – in-the-moment coaching, which is an intended TTS structural feature. In more traditional in-person circumstances, it is not the norm to provide in-the-moment feedback to student teachers as they develop their practice with students, although perhaps it should become more commonplace. Rather, feedback often arrives after the teaching episode is over, out of earshot from students and out of the context of instruction. However, in an online setting, student teachers and their attendings were able to communicate quickly through chat features, which is essentially out of the earshot of students, and provide course correction or suggestions as the attending saw fit. This form of feedback not only supports teacher learning, but it also enhances student learning in that the attending is able to quickly intervene to better support student learning outcomes. As Iris described:

This is one thing you probably can't get necessarily well in person, but while we're teaching, we have our own chat so **sometimes Matthew will throw in recommendations while we're teaching, so we can see it and get it like, okay, let me do that now. Which I think would definitely have been hard to do in person**, without him being like, hey you should do this, you know, out loud type of thing. So, I definitely say that was one of the biggest supports I really appreciated throughout this past semester (Interview, 4/20/21, emphasis added).

In the excerpt above, Iris described how Matthew’s use of the chat feature was helpful because it would have been difficult to give suggestions out loud in the class. However, as TTS model is designed to attend to both student *and* teacher learning, this comment from Iris begs the question: why not give suggestions out loud in class, or at least more instantaneously than is the current standard? TTS model intends to shift the school culture away from complete teacher autonomy and towards intergenerational structures to support development. Perhaps Iris and Aaron’s experience with Matthew’s virtual in-the-moment feedback is a starting point to consider how we translate such a structure to in-person learning environments.

Lessons from Participants’ Experiences in a Developing, Virtual School Culture

“I think learning happens best together and I think unlearning happens best together.”

-Stella, Interview, 2/16/21

In the above quote, Stella captures the importance of building a strong school culture dedicated to student and teacher learning through ARSJ STEM teaching practices. Just as members of TTS community arrived with various stances and approaches to practice, such perspectives are not changed in a vacuum nor are they changed overnight. As Stella pointed out above, both learning and unlearning happens best together. Such learning and unlearning have the potential to take place within intergenerational structures in TTS model. However, not all features were able to be enacted during the 2020-2021 virtual school year. The data analyzed throughout this chapter suggests that TTS participants were able to enact, observe, and consider elements of ARSJ STEM teaching practice, though perhaps in more truncated ways than if learning was situated in an in-person setting. Furthermore, it appeared as though participants were focused on different ARSJ STEM teaching practices from one another, which could have led to perceived differences in teaching philosophy or approaches to practice across the school

culture. Perhaps it is not realistic to expect student teachers and residents to observe and enact all ARSJ STEM teaching practices within a unit of instruction, but this could be an eventual goal that is supported by intergenerational communities of practice consisting of interns, student teachers, residents, attending teachers, and attending teacher educators. Providing a glimpse into the virtual school culture throughout the year of data collection highlights the importance of further building out TTS features to support the learning of ARSJ STEM teaching practices across participants.

The virtual nature of the school year created unique challenges to building and enacting intended TTS features to support student teacher and resident learning. Simply put, this chapter highlights how difficult it was to build a school culture during a pandemic year. As Stella pointed out in an exemplar presented previously (p. 133), students were faced with immense and immeasurable trauma outside of the school space. Further, teachers were faced with extreme pressure to continue performing at pre-pandemic academic levels, which was simply not possible given the circumstances. Thus, it is no surprise that student teachers and residents faced such challenges during the 2020-2021 school year. However, we can use this year of data collection as lessons in how to move forward. First, we must consider how student teachers, residents, attending teachers, and attending teacher educators approach ARSJ STEM teaching practices. Understanding where everyone starts is critical for both learning and unlearning to take place. Secondly, it is crucial to prioritize TTS community-wide learning opportunities to further develop visions for ARSJ STEM teaching in practice. What are the implications for building a shared vision if TTS does not have features in place for examining our visions, commitments, and principles related to ARSJ STEM teaching practices? Lastly, we must further understand the scope of incoming STEM student teachers' and residents needs in learning to teach in ARSJ

ways. How we address such needs is critical to supporting teachers and, in turn, students' STEM sensemaking, as TTS continues to grow.

Chapter 5 Participants' Engagement in Opportunities to Learn ARSJ STEM Teaching

In the previous chapter, I explored participants' perceptions of and experiences within a developing school culture during a year of online teaching and learning. Although participants were able to observe and enact certain elements of ARSJ STEM teaching practices, learning opportunities were hindered by isolated and relatively small communities of practice, as well as technological and spatial constraints of learning to teach online. Now, I turn to the second sub-assertion, which explores how participants engaged with and took up opportunities to learn ARSJ STEM teaching practices made available within TTS model. To start, I present such opportunities to learn, both as designed within TTS model, and as they presented themselves through data collection and analysis. Then, I attend to participants' opportunities to learn ARSJ STEM teaching practices through interactions with attendings and each other. Across interview and classroom observation data, I found that participants brought varying perspectives and levels of reflexivity and agency to their interactions within TTS. Throughout this chapter, I explore how such variations influenced how and the extent to which opportunities to learn were taken up by student teachers and residents. As will be exemplified, increased levels of reflexivity and connections to agency translated to more successful engagement in and uptake of opportunities to learn. Below, I present a portion of the key linkage chart that corresponds to the findings presented throughout the chapter.

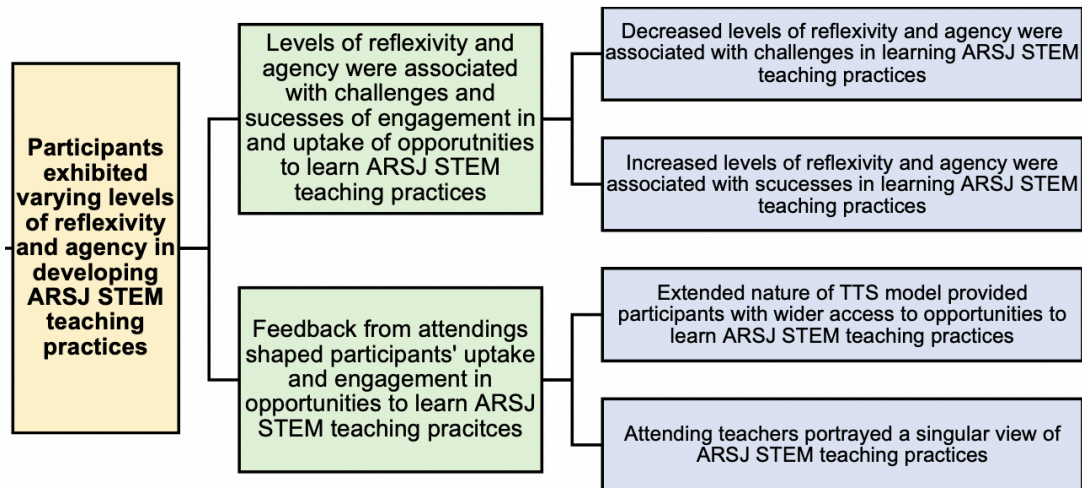


Figure 5-1 Chapter 5 key linkage chart segment

Opportunities to Learn ARSJ STEM Teaching

I begin this chapter by presenting the opportunities to learn (OTL) made available to TTS participants throughout the 2020-2021 academic year. Although some OTL were designed ahead of and informed data collection, other OTL arose out of participants’ needs throughout the school year and interactions with colleagues and students. Thus, I chose to present all OTL within this findings chapter as I explore how participants moved within and attempted to take up such opportunities in practice. OTL that arose from data analysis tended to be participant-driven and were typically more informal than OTL that were intentionally built as part of the model. In the table below, I provide a description of each OTL, along with an indication of who participated and whether it was categorized as formal or informal.

Opportunity to Learn	Description	Designer	Participants	Formal/ Informal
<i>Residency support meetings</i>	Weekly sessions with residents and coaches discussing problems of practice related to ARSJ STEM teaching and resident-guided topics.	TTS Model; Myself and Brooke	Kendall Stella Rachael Brooke	Formal
<i>Morning meetings with STs and AT</i>	Daily meetings to discuss lesson planning, ST and AT instructional decision making, and current	Matthew	Iris Aaron Matthew	Formal and Informal

	events related to ARSJ mathematics teaching.			
<i>Journals</i>	Running record of residents' responses to prompts related to ARSJ STEM teaching and personal/professional goals.	Myself and Brooke	Kendall Stella	Formal
<i>Monthly seminar</i>	Meeting to bring together STs to discuss TTS experiences across disciplines and provide a space for STs to meet and discuss problems of practice with residents, FHS administrators, and university personnel on a rotating basis.	TTS Model	Aaron Iris Social studies ST (+ Additional FHS and University participants)	Formal
<i>Professional development</i>	District-designed and mandated PD opportunities, some focused on ARSJ-specific topics; University-designed PD sessions were continually offered but occurred infrequently throughout the school year.	TTS Model/ FHS administrators / District personnel	Kendall Stella	Formal
<i>Coaching sessions</i>	Meetings between coaches and residents to debrief observations, discuss problems of practice, and co-plan upcoming lessons; Cadence varied based on participants' needs and were both formal and informal in nature (i.e., scheduled weekly and impromptu as needed).	TTS Model; Myself and Brooke	Kendall Stella	Formal and Informal
<i>Observation protocols</i>	Pre- and post-observation tools used by residents and coaches to guide observations of practice and subsequent debriefs; Categories were based on resident's stated instructional goals and elements of ARSJ STEM teaching.	TTS Model; Myself and Brooke	Stella	Formal
<i>Co-planning</i>	Co-development of instructional materials for shared curriculum in advisory period.	Matthew and Stella	Matthew Stella	Informal
<i>Observing colleagues' practice</i>	Residency support meeting assignment to observe problems of practice and how they played out in varying virtual classrooms across the school.	TTS Model; Myself and Brooke	Kendall Stella	Formal
<i>Communication with colleagues</i>	Emails and online meetings with colleagues to discuss issues related to the school and students, as well as approaches to practice.	Kendall and Stella	Kendall Stella	Informal

<i>Staff meetings</i>	School-wide online meetings dedicated to whole team discussions on school practice and policy, grade level teams, content teams, and independent work time.	FHS Administrators	Aaron Iris Kendall Stella	Formal
<i>Summer literacy coursework</i>	Summer course that engaged participants in disciplinary literacy strategies and planning support to incorporate such strategies into teaching practice.	TTS Model; Brooke and PI	Kendall Stella Additional FHS teachers	Formal
<i>Summer 2020 planning sessions</i>	Regular meetings with residents and coaches to support the ongoing development of curriculum for the upcoming 2020-2021 school year.	TTS Model; Myself and Brooke	Kendall Stella	Formal
<i>Conversations with students</i>	Discussions with students centered on both disciplinary understanding and personal interests.	Aaron Iris Kendall Stella	Aaron Iris Kendall Stella	Formal and Informal

Table 5-1 Opportunities to learn ARSJ STEM teaching made available through TTS model

Varying Levels of Reflexivity and Connections to Agency: Factors Affecting Interactions

Within and Uptake of Opportunities to Learn

Residents Kendall and Stella each approached learning to teach science and engineering, respectively, with different learned ideas about teaching and about learning to teach, ideas that shaped their engagement and movement within opportunities to learn and their connections to agency to improve upon their developing practice. My observations suggest that whereas Stella was apt to welcome feedback, engage in reflection, and iterate on her practice, Kendall was hesitant to reflect, accept feedback, and adapt instruction as necessary. By and large, both residents engaged in similar OTL including individual coaching sessions, co-planning support, and residency support meetings. Thus, I hypothesize that differences in residents' approaches to practice were due in part to their reflexiveness and connections to agency in shaping their STEM teaching practice towards ARSJ aims. Furthermore, understanding how preservice teachers' stances on student and teacher learning shaped their engagement in and uptake of opportunities

to learn, as well as their commitments to improve their teaching offers implications for iterating on the structures and practices necessary for a strong ARSJ-oriented TTS.

Throughout this chapter, I use the term reflexivity to characterize the examination of personal connections to power and privilege. Reflexivity with respect to ARSJ STEM teaching corresponds to developing a critical eye towards one's respective STEM curriculum and approaches to teaching, as well as recognizing one's role in needing to improve on practice. I use the phrase 'connections to agency' to refer to how participants viewed themselves as agentic within the classroom space, or not. How participants perceived themselves as agentic in developing their practice and transforming STEM learning experiences for youth was important in understanding how TTS model both supported and constrained such development. If participants arrive at TTS with initial varying levels of reflexivity and connections to agency, how do we support teachers in learning to look inward, examine personal connections to power and privilege, and perceive themselves as agentic actors in transforming STEM learning environments towards ARSJ aims?

I begin this section by exploring Stella's engagement with OTL and her approaches to practice. Then, I will turn to Kendall's experience in TTS. Subsequently, I will analyze the experiences of student teachers Iris and Aaron to think about how TTS model could prime participants to engage in feedback and iterate on practice as an ever present and necessary cycle of support throughout one's teaching career.

Learning to Engage: Successes in Translating Opportunities to Learn into Practice

Stella arrived at TTS with a history of exploring her own positionality as a second-generation Nepali immigrant from an upper-middle class area. Throughout our time together, Stella often spoke about her own experiences as a person of color and how these were decidedly

different from those of her students, the majority of whom were Black. Stella made it clear that when defining and having discussions about ARSJ STEM teaching practices, students and their experiences are at the center:

I think the work of antiracist and socially just teachers is to center the voices of the most marginalized people in the work that we're doing, knowing that those people often go unheard, are unrepresented. So that means for me, pulling away from my own voice as a teacher (Interview, 11/2/20).

Further, Stella elaborated on this idea in a journal entry, stating, “in conversations about social justice and antiracism, I never want to position myself at the center of any conversation, I mostly want to open up a space for students to share their thinking” (Journal Entry, 11/17/20). In these excerpts, Stella demonstrates her reflexiveness as she decentered herself within conversations about antiracism and social justice with students and begins to work towards an understanding of the ARSJ STEM teaching practice of *positioning students as experts in their culture and agentic changemakers*.

Stella’s use of critical self-reflection was seen in multiple OTL throughout her time in TTS. Residency support meetings and individual coaching sessions provided opportunities for Stella to reflect on her positionality and how this influenced her teaching and relationships with students. As Stella pointed out, time to reflect with others was where “the most learning” happened, pointing out that she enjoyed having others watch her teach because “I think I grow the most when I’m able to reflect with other people” (Interview, 2/16/21). Such participation in a community of practice centered on the continuous development of ARSJ STEM teaching practice appeared to provide Stella with the structure necessary to examine her own positioning in relation to her nascent teaching practice. Stella acknowledged the role of “consistent and

constant reflection” with others in thinking through how her practice was “socially just? How [was] it antiracist?” Furthermore, she said, “I personally am reflecting on my own identity and privilege and understanding my relationship with whiteness as a concept and how I'm breaking that down for myself” (Interview, 11/2/20). Similarly, she shared sentiments about personal reflection in her end-of-year interview:

I think [ARSJ STEM teaching] needs to start with **consistent reflection and recognition of your own positioning and own experience**. I think that it is really hard to do the work of antiracist teaching or socially just teaching without looking inward first and consistently and constantly to understand who you are and how you've experienced the world (Interview, 6/29/21, emphasis added).

Stella’s acknowledgement of “consistent reflection” as an important tool to consider one’s positioning, power, and privilege further demonstrates her relatively high levels of reflexiveness and engagement with OTL to develop her practice within TTS model. In her approaches to residency supports, Stella appeared to position herself as a learner, as a student of teaching, rather than a teacher who was simply there to teach and not necessarily *learn*. Such reciprocity within TTS model characterized her engagement with OTL – as she learned to engage with TTS support structures, she explored her power and privilege, as well as her agency as an engineering teacher designing learning environments and experiences for youth. Such analysis points to the importance of continuing to build out and develop TTS features of developing communities of practice, as well as embedding supports for novice teachers inside the classroom to review and reflect upon their teaching.

Stella’s engagement within OTL made available through TTS translated into notable changes within her teaching practice. For example, individual coaching sessions served as a

space for Stella to not only reflect on her positionality and aspects of her practice, but also served as meaningful support to connect to her agency as an ARSJ engineering educator and iterate on her human centered engineering and design curriculum. In the paragraphs that follow, I demonstrate how Stella made use of and took up OTL made available through coaching sessions to create a more inclusive and just version of students' final assessment, demonstrating enactment of the following ARSJ STEM teaching practices:

- 1. Position students as experts in their culture and agentic changemakers*
- 2. Develop STEM tools to address community concerns*
- 3. Critically examine STEM curricular materials*
- 4. Design responsive evaluation and assessment measures*

Stella's human-centered engineering and design class made use of a spiral curriculum that engaged students in successive design cycles throughout the school year focused on different facets of school community problem spaces. The design thinking process, or design cycle, is a series of steps that engineers use to define and explore a problem space while working towards designing and implementing a solution. Figure 5-1 (below) demonstrates an example of the design cycle Stella used in her class with students. Stella would often use images such as this to ground students and help them to better orient themselves within the data-driven design cycle, always referencing the end goal in mind: design a solution and present your findings to the school community.

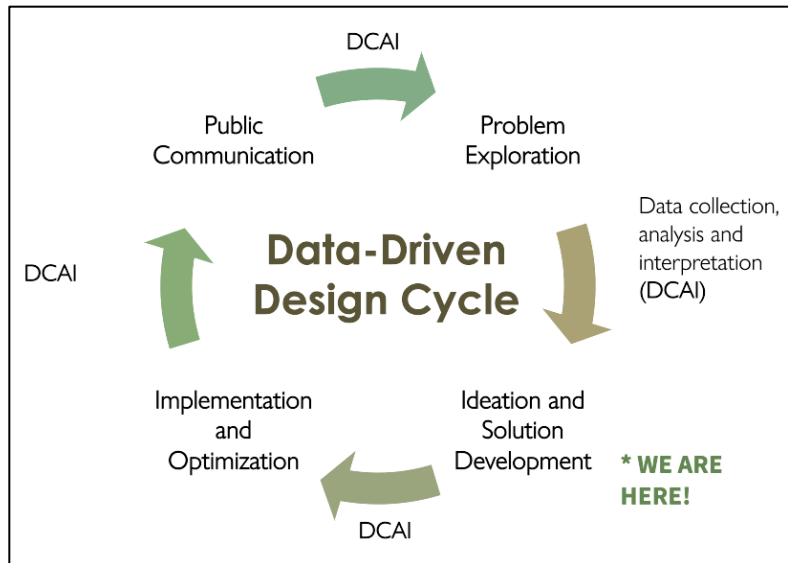


Figure 5-2 Data-driven design cycle used in Stella’s human-centered engineering and design course

Each data-driven design cycle was considered a unit in the class, and students engaged in engineering and design work that culminated in a presentation made to the school community. The curriculum was ‘spiral’ in nature, in that it progressively built upon engineering concepts and skills throughout the year, always rooting itself within the design cycle. For example, although the concept of data collection, analysis, and interpretation (depicted as DCAI in Figure 5-2) was introduced at the beginning of the year in the first design cycle, students would return to DCAI within each successive design cycle. At each touch point, students’ use of data collection and analysis tools would become more complex and varied, as students made decisions around which tools would best suit their particular problem space or the questions they asked.

Up until the spring of 2021, design cycles in Stella’s engineering class would culminate with a public communication component where students would present their work in a poster session to the school community. Although public communication is an important aspect of design work, the presentations happened during class time, which prohibited participation from community members who were busy during the regularly scheduled work and school day. Given

university personnel's relatively flexible schedules and interest to participate, the audience became very university-centric, most of whom were White (myself included). Stella engaged in the ARSJ STEM teaching practice of *critically examining her curriculum* and recognized this did not accurately represent students' community or provide the most meaningful feedback for students' community-centered designs. It also created a potentially problematic power dynamic where visitors were seen as holders of knowledge, since audience members gave feedback and were included in the grading process. Given these factors, students felt that visitors who were assessing their work had insights into the design process that students themselves did not. On the contrary, it was most likely the case that students knew much more about design thinking and the problem space than university visitors. This was tricky because as the teacher, Stella wanted to instill a sense of feedback as positive and iteration as a natural, and important, part of design. However, as a resident-attending teacher educator team, we also did not want it to be the case that students came to associate feedback, and in turn improvement, with consultation with White folks. Instead, we attempted to *design learning opportunities that question and reimagine the status quo* and worked to move away from White savior complex tropes in the curriculum by incorporating students' community in every aspect of design, including the final presentation. Our goal was to send a message that "we're not trying to go in and solve somebody else's problem, nor does somebody need to come in to solve your problem" (Stella, Interview, 2/16/21). Through this critical analysis of the curriculum, Stella identified areas of improvement and worked to *position students as experts* as they *designed engineering solutions for community issues and concerns*. Furthermore, Stella worked to create a more *inclusive assessment*, which would be *responsive to students' needs* and elevate student and community voices more prominently.

Over the course of several coaching sessions, Stella and I worked to create a presentation format that was more antiracist by elevating the voices of her Black students and the surrounding communities of color, and more socially just by widening access to presentations beyond the typical school day. Ultimately, Stella developed a format for students to record their presentations using Flipgrid, an online video recording and editing tool, and send it out to chosen family and community members for feedback. Audience members then had the opportunity to record their feedback or make comments on the video for students to review. When presenting these ideas to students, Stella showed students how she used “the same design cycle as [students] do to plan this class” creating slides to demonstrate her problem space: “Our public communication format (including design briefs and final presentations) seems to be stressful without feeling engaging or authentic for all students” (Classroom Recording, 5/19/21). She also demonstrated how she analyzed data from student feedback surveys and coaching sessions, ultimately resulting in the new format. Stella explained to students:

The current public communication format prioritizes bringing in people who can make it during class. They have to be able to make it on time here to watch your presentations. Because of that, our audience is usually people from [the university] and staff, who I invite and bring in, but in the ways that I do that, it excludes people like students’ families, friends, and other people who are important to students, and who can also add a lot of additional feedback to the problems. But they may be excluded either because they can’t make it or they weren’t invited to begin with, which is a problem. The solution I came up with should allow audiences to engage in presentations regardless of if they can make

it to presentations or not and bring in a broader audience that students want to engage with for their design work (Classroom Recording, 5/19/21).

Although this change in presentation format did allow for more community participation, not all students seemed to prefer this format over the more traditional poster session. Stella then continued to reflect on how it could be made even better for students in the future, demonstrating her commitment to continuous improvement on her practice. Upon receiving feedback from students, Stella realized that the shift in presentation format placed a bigger ask on some students to utilize tech tools with which they were not wholly familiar:

Students are bringing in the community that we're centering around for our projects with people that they care about and shifting who the audience is, but then also **how is this inequitable in that we need to learn a new tech tool, we're having trouble with corrupted videos, we need to do all these things that could be harder for some students than they could be for other students.**

So, I made this change. I identified the problem, and I made this change to said problem, then also got feedback and had my own observations. Knowing that my goal was to make our project audience maybe more representative and have a format that was a little less burdensome, a little less stressful for students, how are the ways that it actually achieved that? How are the ways it absolutely did not achieve that and for who? Was it better for students who are really great with tech, and was much harder for students who really struggle with that? And so, in the future, thinking about how can we reduce the burden of that? So, yeah, **I guess in my practice that's the biggest part of setting goals, making changes, and**

then actually seeing how those goals are met, and if they are. And if not, what do I need to do to make things better? (Interview, 6/29/21, emphasis added)

Based on the excerpts above, it appeared that Stella's use of the design cycle allowed her to analyze, iterate, and reflect on her practice in ways aimed to center students and their community. She noted that although her goals were to make presentations more equitable, the format she chose may not have achieved this in all cases. Then, she goes on to talk through her reflection process and what this meant for her teaching, not only describing her reflexiveness but also her connections to agency as a teacher: Stella said she identifies changes to be made, makes those changes, and then identifies areas of her practice for improvement. Identifying areas of improvement and implementing feedback demonstrates both her reflexiveness and agency, in that she had the power to both identify improvement and change her practice for the betterment of student learning. Furthermore, the above exemplar is indicative of Stella's dual commitments to ARSJ STEM teaching practices and her own development as a teacher.

Throughout her interviews, Kendall also examined her relationship to reflection with others, stating that the reason she was "getting better at analyzing and reflecting on practice" was due to "talking to [Author] regularly and Brooke" (Interview, 2/4/21). In addition to talking with attendings, Kendall started to hint at the benefits of intergenerational learning, as she spent a lot of time reflecting with Stella, a near-peer who was a resident one year ahead of her in TTS. Kendall stated:

I'm definitely learning a lot just from going through similar things with [Stella], or even just talking about this is how it went. I think even just answering that question, this is how that went, makes you kind of see it in a way that may be different from how you were originally processing it. So, yeah, **that reflective piece, I think**

that's a lot of what's helped me learn with just kind of ways of viewing the practice (Interview, 2/4/21, emphasis added).

Kendall's interview response above highlights the importance of reflection in viewing her practice in different ways. She mentions that *going through similar things* with Stella is a benefit to the model because it allowed her to process how her practice went in ways that she might not have thought about otherwise. For Kendall, however, it appeared as though the conversations about her practice or talking about *how it went* was where the engagement paused. Although Kendall engaged in reflection through residency support meetings and coaching sessions, these conversations did not always translate into meaningful changes in her practice. As will be demonstrated in the sections that follow, Kendall's resistive nature to feedback and, in turn, connections to agency, impacted the extent to which she engaged with and took up opportunities to learn and develop elements of ARSJ STEM teaching practice.

Resistance to Engagement: Challenges in Moving Opportunities to Learn into Practice

In the previous section, I explored how Stella's approach to reflection and feedback within TTS model shaped the ways in which she took up OTL in her practice and incorporated elements of ARSJ STEM teaching practice. Now, I turn to data highlighting challenges in moving OTL into practice.

Throughout the 2020-2021 school year, instructional pacing was one of the main problems of practice Kendall and I worked on in our coaching sessions together. As mandated by the district (with significant flexibility for curricular adaptation), Kendall was working off a web-based and problem-based curriculum that was separated into four major units to be covered throughout the year (Concord Consortium, 2020). However, by the end of the school year, students in Kendall's class had covered only one unit. Prior to starting this unit, Kendall decided

to design a pre-unit meant to introduce students to science through readings and discussion, as well as begin to develop their own identity as science students. The pre-unit, designed to span two weeks of instruction, lasted about six weeks. In turn, Kendall did not begin work on the first unit, designed to investigate interactions between charged and uncharged objects, until late October, which reduced students' opportunities to engage in STEM concept and skill learning throughout the school year. Throughout the pre-unit, students read about various scientists from minoritized backgrounds, engaged in literacy strategies, and met with practicing scientists, engineers, and public health professionals via Microsoft Teams. I had initially adapted materials for Kendall to use from the Stanford NGSS Integrated Curriculum (2018), making them more online friendly and focusing on students' development of science identity (e.g., who does science?), as well as an outline for a final assessment where students would share what they learned with the class through presentations. Instead, Kendall "used little to no materials made available for her and chose to find and create the materials largely on her own" (Field Notes, 10/16/20), which would become indicative of her hesitancy to accept, or knowledge of how to integrate, support throughout the school year. At the start of the unit, Kendall was struggling with how to support students in annotation, a literacy practice she wished to highlight throughout the year (Journal Entry, 10/1/20). She consulted with me and Brooke, an attending teacher educator with extensive expertise around literacy instruction, about how to support students in annotation. At first, Kendall's queries were focused on reading level, and she wanted to know if the texts she chose were appropriate for ninth graders. Instead, Brooke "encouraged Kendall to think more about what she was asking of students within the readings and to perhaps work towards having students make connections across a set of readings" (Field Notes, 10/16/20). In response, Kendall created a graphic organizer where students were asked to record data about

two different scientists, spread over about a week of instruction. In the end, students recorded data about two scientists, side by side, yet “it did not appear that students were asked to synthesize across” (Field Notes, 10/16/20). In this instance, not only did Kendall reduce the pace of the class, but she was also met with challenges when attempting to take up feedback from attending teacher educators, perhaps a quality indicative of a first-year teacher. Thus, although the pre-unit had the potential to connect to ARSJ STEM teaching practices of *developing disciplinary identities* and *designing learning opportunities to question the status quo*, challenges in pacing and feedback uptake lessened the potential to do so.

Kendall’s use of her own materials and the interpretation of feedback demonstrates Kendall’s reflexiveness and connections to agency as a new teacher. She developed her own materials with the best of intentions to create meaningful learning opportunities for students in her class. When presented with feedback about specific problems of practice, such as pacing, however, Kendall shifted focus away from her learning as a teacher to the virtual nature of the school year and students’ overall engagement in her science class. Rather than engage in reflective learning opportunities to determine how to shift instruction towards more ARSJ aims through her agency as the teacher, Kendall found herself restricted by the context of the virtual school year and the curricula she was tasked with covering. Furthermore, Kendall’s lack of content coverage in her course (i.e., covering one unit throughout the year) could be viewed from two angles. First, in reducing the pace of the course, Kendall wanted to ensure that all students were participating, engaging, and learning in her class. Coming from a background of “biomedical engineering and then chang[ing] to computer science” (Interview, 10/20/20) as an undergraduate at a prominent STEM institution, Kendall came to TTS with a deep and thorough understanding of her content knowledge. Hence, she recognized the importance of understanding

foundational science concepts and skills to apply in future school or career environments. It is also prudent to consider the virtual nature of the school year in considering Kendall's ability to assess student work and participation levels. Students were not asked to turn on their cameras, which made it difficult to consistently assess understanding. Kendall often found it difficult to move on in the curriculum when she did not have a sense of all students' sensemaking, or one hundred percent turn-in rate on assignments. The second angle from which the situation can be viewed is that significant reduction in content coverage not only denied students from participation in opportunities to build disciplinary concepts and skills, but it also could have been a reflection on Kendall's expectations of students. Activities designed to last about 20-30 minutes, such as completing one column of a graphic organizer, would oftentimes span multiple class periods given low levels of student completion and participation in class (Field Notes, 10/6-10/7/20). For example, Kendall wrote that she "gave students another day to revise their models to include everything we talked about in class (which I should have re-stated in the directions) because so many students didn't turn in their models or left off charge or force" (Journal Entry, 12/8/20). Extending the assignment another day to give students time to turn in or change small parts of their work could have been approached differently, perhaps as a group activity during class if she noticed a trend in student sensemaking and participation. Although Kendall further reflected on how this could translate to expectations of students – "I'm wondering whether I was still holding students to high expectations by giving them another day to complete the assignment" (Journal Entry, 12/8/20) – I did not observe noticeable changes in her practice or a notable increase in instructional pacing as the year progressed.

As I observed Kendall's practice throughout the year, I decided to talk with her about pacing, even offering ways to think about how to adapt curricular materials or adjust student

participation or assessment. For example, Kendall would often ask all students to respond to an icebreaker question at the beginning of class by moving down the class roster and having students turn on their mics and share out. Although this worked to build relationships amongst students, it would often take upwards of 15 minutes to complete, encroaching on vital science instructional minutes. However, when students were engaging in scientific disciplinary work, the same participatory expectations were not in place and only a handful of students would respond via the chat or occasionally via the microphone. I suggested that students instead participate as they would in the icebreaker to a Do Now question focused on building scientific concepts and skills, as well as combining certain activities as laid out by the curriculum to move along a bit faster. In response, Kendall wrote the following in a survey requesting feedback around residency supports:

I have felt this year like I am being rushed to move on or move quicker through concepts than students can actually keep up with. I know I am "behind" in the curriculum. **I know it would be great if we could move faster for measuring growth purposes.** However, the kids are not showing mastery. The kids are not turning in work and not showing mastery on their work. On my '2021 changes to physical science survey' I had students complete this week, a handful of students felt like the workload was still too much and too challenging. Though not all students felt this way, I still do not want to move on just to move on. Therefore, **I do not want to keep being reminded to move quicker through material than we are.** I do not feel like it is always apparent just how difficult and exhausting it is to keep "teaching" when so many students do not show up to class and so very few participate. This makes it very hard to just continue with material, when I

know so few are actually getting anything out of it. Instead, **I would like to focus on things I can control like creating better formative assessments and measurable objectives**” (Kendall, Residency Supports Feedback Survey, 1/8/21, emphasis added)

In a subsequent coaching session, Kendall shared with me that her attending teacher, Kira, also made comments about her pacing, which she did not appreciate. Thus, it appeared as though pacing was of concern even in her pre-service training, across multiple support systems. After the coaching session, I referred to the pacing guide I had developed for Kendall over the summer prior to the start of the school year and concluded that she was three months behind what we had planned. Reflecting on this, I wrote “we are currently on activity 1.4, which was supposed to happen on October 1st. So, while I do acknowledge Kendall’s feelings, I do not think comments about pacing are completely unwarranted” (Field Notes, 1/14/21).

Analysis shows that Kendall brought up three main points in her feedback survey. First, she mentioned that she knew it would be great to *move faster for measuring growth purposes*. Although measurements of student growth are important feedback mechanisms for instruction, it is certainly not the main purpose of moving more quickly through the science curriculum. Instead, opportunities to learn through intergenerational structures could have supported Kendall in reorienting her thinking about movement through the science curriculum towards both student engagement and developing scientific concepts and skills, all of which could have been facilitated through more intentional focus and incorporation of ARSJ STEM teaching practices. Moving at a much slower pace not only disengaged students who were participating, but also denied access to 75% of the curriculum laid out for ninth grade physical science. As laid out in the ARSJ STEM teaching practices defined throughout this dissertation, STEM concept and skill

learning is foundational and necessary for transformational STEM learning experiences to take place. Thus, even if Kendall had found ways to incorporate students' community or draw on their cultural knowledge in classroom interactions, the nature of such practice was not wholly connected to science concept and skill learning and, therefore, not supporting students' sensemaking to the fullest.

Second, Kendall made it clear that she wished not to continue receiving feedback around her pacing, citing the challenges of teaching in an online environment and feedback she received from students about the class being too challenging. In this instance, she positioned feedback from attending teacher educators as something with which she did not want to engage. Last, Kendall mentioned that she wanted to focus on things she could control, such as assessments and objectives. As her attending teacher educator, this was important feedback for me to receive, as it signaled where she viewed her connections to agency as a teacher and perhaps where she wanted to focus our sessions together. However, after making this statement, Kendall did not continue to work on her science assessments and objective writing throughout the year, calling into question her justification for resisting feedback. For example, in her final course assessment, Kendall was concerned that many students did not complete one of two models of interactions between a charged and uncharged object. In our coaching session immediately following the class:

I suggest that she simplify her slides because there is a lot of text, and it could be confusing students. I talk through what the essence of her models are – 1) model an atom, and 2) model an interaction between a charged object and an uncharged object – and encourage her to make bullet points on the page to guide students through what she actually wants. She is hesitant because she doesn't want to simplify or scaffold students too much because it is a test. I remind her that it is

about what you want to assess, not about tricking students or testing their test taking skills at this point. She says she will combine the first two models and then make her text more accessible to students. She is frustrated because she says students have seen these scenarios many times and so they should know how to make these models (Field Notes, 6/8/21).

The field note data above suggests that Kendall believed exposure to content alone should have translated to student sensemaking, further separating herself from pedagogical responsibility and connections to agency. Instead, Kendall's adaptation to her assessment could have been viewed as an important measure towards *responsive evaluation and assessment measures*.

Following Kendall's feedback on residency supports, I enlisted the district for support and contacted Holly, a former colleague of mine who worked in the district's science curricular department and asked if she would meet with both me and Kendall to discuss pacing and district support opportunities. After some time, we were able to schedule a meeting where Holly relayed that most teachers in the district were moving at similar paces to Kendall and she was working to "make sure teachers [did] not quit" (Field Notes, 3/3/21). Her advice to Kendall was to focus on the subset of students who were "getting it" and move on according to their pace, as opposed to trying to always reach all students. Throughout the meeting, Holly was very sympathetic towards Kendall. After the meeting, I thought about what it meant to support teachers and whether the pandemic created a unique context where teachers' mental and emotional health truly came first, which is extremely important even under 'normal' circumstances. Perhaps because Kendall was not attuned to receive critical feedback prior to starting the virtual school year, it was not the time to introduce her to such practice. At the end of my field notes, I wrote the following:

I still don't feel like it is equitable or just to not cover the content that students need to compete or succeed in subsequent science learning opportunities. Maybe this year is just a wash, but that does not sit well with me (3/3/21).

Instances such as this highlight the potential for TTS structures and practices to be designed that support novices in finding an important balance between presenting students with new ideas at a reasonable pace and ensuring meaningful student learning.

In addition to the above analysis of Kendall's feedback response, I observed at least four instances where Kendall mentioned students and their challenges within the survey (Residency Supports Feedback Survey, 1/8/21, emphasis added):

1. I am being rushed to move on or move quicker through concepts than *students* can actually keep up with
2. *the kids* are not showing mastery
3. *the kids* are not turning in work
4. *so few [students]* are actually getting anything out of it

In these instances, Kendall appeared to shift focus for her lack of content coverage onto students. Instead of displaying commitments to developing her teaching practice and connecting to her agency as a teacher, Kendall instead stated that the reason her class was not moving forward at an appropriate pace was due to student ability (*than students can keep up with*), sensemaking (*not showing mastery*), compliance (*not turning in work*), and engagement (*so few are getting anything out of it*). As touched upon in the previous chapter, Kendall wrote the following in reference to expectations of students and having an asset-based mindset:

I believe I have done this to the best of my ability while also being realistic. I think the best prediction of future behavior is past behavior, so I keep that in mind in terms of expectations for students (Journal Entry, 12/14/20).

An example of her expectations of students in practice comes from a debrief with Kendall the day after parent-teacher conferences towards the start of the school year. In our meeting, Kendall recapped the experience with students and parents, and I recorded these thoughts in the field notes presented below:

Kendall said **she was very surprised to hear from many parents that their students were valedictorian at their old schools because they are not doing particularly well in her class (mostly B's)**. I said this was interesting and she'll have to be sure to play on students' strengths throughout the year. One parent told Kendall that their son has a hard time with independent work time and asked if she could check in with him more. I used this as an opportunity to talk with Kendall about framing the work time around things that students have to do during class instead of "if you feel like it" (a phrase she used in class on 10/13/20). Kendall said that she does this because she knows not all students are in an environment where they can record videos or do work silently so this is why she gives them the choice. I encouraged her to frame this more as you should work towards these things during class time then check in with her if there are issues. She said she would give a list of recommended items, but she does not want to enforce certain assignments due during class time. I asked if her saying "do it when you want" impacted her turn in rates. She said it did not because **there are some students who will always turn in their work on time and they**

turned it in. Then, those who were going to turn it in late do so anyway. I

cautioned her to stay away from categorizing students like this, especially so early in the school year (Field Notes, 10/15/20).

First, Kendall mentioned her surprise at hearing students were valedictorians at their previous schools since they were not doing well in physical science. Although it could be the case that different schooling institutions have different academic demands and standards for students, it could also be the case that students possessed untapped strengths and potential for Kendall to tap into in her class, which could have connected to *positioning students as experts and agentic changemakers* and *drawing on students' cultural knowledge and capital*. In this instance, Kendall could have reflected on how she shaped learning experiences for students and how to build off students' strengths to encourage participation and engagement in meaningful learning.

Second, I used this coaching meeting as an opportunity to address Kendall's use of the phrase "if you feel like it" to refer to assignment deadlines and structuring student work time in class. As the data above demonstrates, Kendall's response was two-fold: 1) she wished to be responsive to students' learning environment situations and needs, and 2) she indicated that flexibility in student work time did not impact assignment turn-in rates because students were either going to turn in their work on time or late depending on the student. Being responsive to students' out-of-school contexts was an important additional layer for teachers to consider during the virtual year of instruction. However, even after a parent requested more structure and check-ins with their student during independent work time, Kendall indicated that the way she structured deadlines during class time had no effect on students' actions. This response only further disconnected herself from her agency as a teacher and shifted responsibility for student academic outcomes almost fully onto students. Thus, although Kendall's rate of content coverage could be viewed as

a benefit to her students, data suggests that decisions about what and how she presented material to students stemmed at least in-part from her mindset around her role and development as a teacher and expectations of students.

It could have been the case that Kendall was simply too overwhelmed as a first-year teacher learning to teach through a pandemic year to fully engage in OTL and develop ARSJ STEM teaching practices. Further, she may not have possessed the pedagogical knowledge necessary to incorporate feedback into practice. Toward the end of the school year, Kendall reflected:

I've never done this full-time teaching thing before. I want to feel more like an expert in this subject, I want to feel better about coming up with a project, and better about creating rubrics, and better about which things I want to be creating, and why it matters to create it that way... and I don't quite always know how
(Interview, 6/24/21).

Here, Kendall demonstrated her desire to improve her practice, yet she admitted that she did not always know how. It is important to note that Kendall was offered multiple TTS supports to develop unit and lesson plans alongside university personnel during both the school year and the summer leading into the 2020-2021 school year in the form of paid graduate course credits. Efforts to engage Kendall in summer work were met with requests to postpone meetings (Personal Communication, 7/17/20, 8/12/20) and overall feelings of being overwhelmed. Thus, although Kendall expressed interest in developing her practice, hesitation to fully participate in support structures could have inhibited her growth as a teacher.

In the section that follows, I explore student teachers' pre-service experiences within TTS model and how their participation within a supportive community of practitioners appeared to

prime them for observation and feedback towards the development of ARSJ STEM teaching practices.

Creating Pathways towards Agency and Productive Feedback through Student Teaching Experiences

In the previous sections, I explored residents Stella and Kendall's learning through supports made available within TTS model. In doing so, I demonstrated how differences in participants' reflexivity, connections to agency, and in turn commitments to improvement on practice, shaped the ways in which they engaged with opportunities to learn ARSJ STEM teaching practice and, ultimately, how this influenced their instruction. Now, I turn to analyses of student teachers Iris and Aaron's experiences with their attending teacher, Matthew, in a mathematics classroom. As demonstrated throughout the subsequent paragraphs, the structures put in place in Matthew's classroom began to create a pathway for Aaron and Iris to view their role in TTS as both teachers and learners, creating opportunities to connect to agency and develop perceptions of ARSJ STEM teaching practices. Aaron and Iris's engagement within an embedded community of practice appeared to prime them both for participation in productive feedback, iteration on practice, and viewing mathematics teaching through a more critical lens. I conclude this section by contrasting Iris and Aaron's experiences with that of Kendall's student teaching experience at Fairfield during the year prior to data collection.

Attending Teacher Feedback: Creating a Critical and Supportive Community of Practice

Math student teachers Iris and Aaron both viewed feedback from their shared attending teacher, Matthew, as one of their most important sources for learning to teach. Aaron went so far as to say, "I owe a lot to Matthew in terms of how much I took away from my whole experience" and if he ever got the chance to become a mentor, it would be "a really nice way for me to pay it

forward” (Interview, 4/27/21). Both Aaron and Iris spent a total of three semesters with Matthew over the course of two academic years as undergraduates in TTS. This extended apprenticeship with the same attending teacher helped to foster a supportive relationship, characterized as a critical and supportive community of practice, between student teachers and Matthew. At the end of the year, Iris reflected that “being able to have been in the same classroom with the same person over time, it really helps them get to know you and know how to best support you and I definitely felt that I got that support whenever I needed it” (Interview, 4/20/21). Furthermore, this support was particularly important to Iris as a woman of color, saying, “sometimes it was a little intimidating, you know, being the only woman amongst men, in a subject that is male dominated, but I always felt supported” (Interview, 4/20/21).

The extended nature of TTS model built a mentor-mentee relationship between Aaron, Iris, and Matthew that allowed for bi-directional questioning and critique. For example, below I present Aaron’s reflection on a time when he observed a potential misalignment between Matthew’s practice and that of his developing conception of equitable grading practices:

There was a part of [the book *Grading for Equity*] that talked about cheating and how if you give a student zero for cheating that's kind of ineffective and listed all these reasons for it, and I know that is something [Matthew] did last year. **But I felt comfortable enough bringing it up like, I read that maybe you shouldn't give students zeros for cheating, but I noticed that you did that last year, can you explain why?** So, I felt close enough to him to ask him his reasoning for it and talk through that (Interview, 4/27/21, emphasis added).

Here, Aaron mentioned his comfort level with Matthew as a factor in bringing up questions about grading practices, working towards a conception of what it means to *design responsive*

evaluation and assessment measures. Although it is not uncommon for student teachers to ask questions of their attending's practice, it is possibly more unusual for the student teacher to challenge or critique this practice upon learning something new either through coursework, text, or otherwise. Perhaps because Matthew presented the text *Grading for Equity* (Feldman, 2018) to his student teachers as something he was striving for, they felt comfortable having these conversations. Nevertheless, without building a critical friendship and supportive community of practice over a period of three semesters, the nature of these conversations could look quite different. However, it could also be the case that Matthew's openness and commitment to both student and teacher learning played a role in these types of conversations. Perhaps without knowing it, Matthew implicitly demonstrated his own commitments to improvement on practice even when placed in a traditionally powerful position as a mentor. Although I do not believe this is unique to Matthew, it is not something I observed with all attending teachers as part of larger data collection efforts within the partnership, which I will expound upon in subsequent sections. These data suggest the importance of developing a community of practice that supports bi-directional questioning and critique, perhaps illuminating how the model supports not only student teachers and residents, but also attending teachers' learning over time.

In addition to critical conversations about practice, Matthew fostered a sense of feedback as the norm with his student teachers by providing in-the-moment comments via virtual learning platforms. Perhaps a silver lining of the virtual 2020-2021 school year, Matthew found ways to provide feedback to Iris and Aaron by utilizing the chat feature in Microsoft Teams. Iris recalled that "while we're teaching, we have our own chat so sometimes he'll like throw in recommendations while we're teaching, so we can see it and get it like, okay, let me do that now, which I think would definitely have been hard to do in person" (Interview, 4/20/21). As

mentioned in the previous chapter, this type of feedback is atypical of traditional student teaching experiences in the physical classroom space. However, based on Iris's remarks below, it appeared that such comments shaped the way both Iris and Aaron engaged with students:

sometimes in moments of silence with the students, he might throw in like 'oh, this might be a good time to do a poll or whatnot.' And other times it'd be like, especially when we were in breakout rooms, since we all can't be in rooms together, sometimes he might say 'oh, I heard this really great conversation from this group, hop into this room, and maybe like chime in on it and whatnot.'

(Interview, 4/20/21)

In these moments of instantaneous feedback, Matthew set the tone for a focus on both student and teacher learning. When Matthew noticed an aspect of the class he wanted to highlight for his student teachers, he pointed it out to them in the moment. In doing so, he recognized that such feedback was not only beneficial to students' mathematics concept and skill learning but would also benefit teacher learning by making the often-invisible work of teaching visible. Even when conducting class in-person with student teachers and youth, Matthew would often pause his practice to point out why he chose to carry out teaching practices or adjust his lessons dependent upon student response (Classroom Recording, 1/14/20). Such characteristics appear to support productive attending teaching, again highlighting both student and teacher learning.

In the section that follows, I demonstrate how different experiences with attending teachers can influence participants' approaches to teaching and engagement within a community of practice focused on developing ARSJ STEM teaching practices.

Singular View of Teaching and Learning: Potential Drawbacks to an Extended Apprenticeship Model

Although attending teachers were rich sources for learning, the extended nature of TTS model has the potential to provide a singular view of teaching and learning, which could restrict teacher learning in some ways. As student teachers work with the same attending teacher over the course of several semesters, some student teachers may come to associate ‘good teaching’ with their attendings’ practice, regardless of how that practice aligns with elements of ARSJ STEM teaching practice. As Aaron pointed out:

a lot of times you’re placed with a mentor teacher that has a more outdated grading philosophy, so you might take something like that away from student teaching and then do that when you start teaching, which isn't going to end the cycle ever (Interview, 12/10/20).

Here, Aaron is talking about a cycle of inequitable teaching practices, such as particular grading philosophies, that possibly stem from observing attendings’ inequitable practice in pre-service training. Luckily for Aaron and Iris, Matthew exuded a commitment to teacher learning and student learning through a lens of ARSJ mathematics teaching. Even so, Iris indicated that she was “worried that I'm just going to try and mimic what I've seen Matthew do” (Interview, 12/17/20). Similarly, Aaron mentioned that his and Matthew’s “teaching philosophies line up” and because of that, Aaron “just adopted [Matthew’s] philosophy” (Interview, 4/27/21).

In a similar, yet distinct experience, Kendall student taught with Kira, an attending teacher with extensive experience in the district in which Fairfield was placed. As we learned, however, extensive experience does not always translate to productive mentorship focused on ARSJ science teaching practice. As a student teacher at Fairfield the year prior to becoming a

resident, Kendall was extremely resistant to additional observation, feedback, and collaboration with other TTS participants beyond her attending teacher. This perspective could have stemmed from Kira, who appeared to exude a ‘closed door’ attitude when it came to her teaching, advocating for fewer observations from TTS support staff. In characterizing her opportunities to learn from Kira, Kendall said that she learned they had “very different ideas of what social justice means.” According to Kendall, when Kira did not agree with something happening in the school, her approach was to “yell at the people, tell them they're wrong.” As an example, Kendall explained:

one time, [the assistant principal] said that teachers couldn't wear Halloween costumes and Kira got so upset. She did a voice message to [the assistant principal] telling her that's not social justice, and Kira said that doing Halloween is a part of her culture (Interview, 10/20/20).

Kira's apparent desire to wear Halloween costumes in the name of social justice does not appear to align with elements of ARSJ STEM teaching practice as defined in this dissertation. However, it could have been the case that Kira was advocating for a more flexible uniform policy, which was enforced at the time when Kendall was student teaching with Kira. Nonetheless, it appeared that Kira's approach to enacting her vision of ARSJ STEM teaching practices did not include productive feedback or conversation with others, which could have influenced Kendall's resistance to iteration and continuous improvement on her practice through TTS supports.

Interestingly, when Kendall was faced with a situation where she felt the school community had wronged her, she approached the situation in a similar fashion, sending an email to school members and partners. Thus, although Kendall attempted to portray difference or distance from her attending teacher, it seemed she did engage in OTL, even if they did not

necessarily align with TTS commitments to antiracism and social justice. However, Kendall pointed out that she appreciated the time she was able to observe others' practice, even though this was not officially part of the model:

I loved last year when I got to observe other people, but I wish that that was more a part of the model, that you observe different people and have these conversations, even if it's just once a week or once every two weeks lunch meeting. I think [during student teaching] a lot of the time I just didn't know other experiences of teachers in the school, so I just kind of worried like, crap, is Kira's ideas what everyone thinks? (Kendall, Interview, 10/20/20)

Given these concerns, it is perhaps prudent to consider how opportunities to learn are designed that incorporate multiple, yet ARSJ-aligned, perspectives on STEM teaching practice.

Learning from Participants' Experiences: Designing Meaningful and Engaging Opportunities to Learn

Concluding this chapter, I offer thoughts on how we can learn from participants' experiences with OTL within TTS model. Despite the virtual nature of the school year, participants were able to engage in meaningful opportunities to learn ARSJ teaching practices and iterate on their developing practice as pre-service and early-career educators. However, participants' varying levels of reflexivity and connections to agency influenced how and the extent to which they engaged with and took up such opportunities. These findings are indicative of the fact that teacher training is not a one-size-fits-all endeavor, although there are common threads that support teacher learning towards ARSJ STEM teaching practice. First, the extended nature of TTS model potentially allows for more time to learn ARSJ STEM teaching practices. Although it was ultimately an imperfect fit, as Kendall chose to leave Fairfield the following

year, the extended time within a community of practice focused on ARSJ STEM teaching could have influenced her overall approach to teaching and learning, as well as how she viewed her role with students. As teaching candidates come from various backgrounds, support can be tailored to individual participant needs to the extent possible. Although it is always necessary to differentiate support, continuity in the program is also important. Hence, recruitment also matters in supporting teacher development, retention, and success. Perhaps Kendall was not meant to teach at Fairfield and be part of TTS, and that is okay. When we consider the support of teacher and student learning through ARSJ STEM teaching practices, having a discerning eye and practical tools to support the selection of those chosen to work with our students is important.

Dual goals of teacher and student learning also extends to attending teachers. As we saw in the differing approaches to mentorship through Matthew and Kira's practice, it is also important to consider how TTS model supports attending teachers in not only participating in but also cultivating a supportive community of practice within their classrooms. Student teachers and residents spend a great deal of time with attending teachers, both as mentees and colleagues. Although Kira's approach to mentorship did not necessarily align with ARSJ STEM teaching in the same ways we saw in Matthew's classroom, perhaps this is not entirely her responsibility. We can place student teachers with attending teachers, but we can also work to support attending teachers in their own developing ARSJ STEM teaching practice. Just as we expect student teachers and residents to view themselves as both teachers and learners, we can also cultivate a community that develops a similar reciprocal relationship with attending teachers. Moving towards ARSJ STEM teaching practices in all aspects of TTS community will require that all TTS participants work towards joint goals of student and teacher learning, including attending teachers.

Chapter 6 Exploring Participants' Perceptions of STEM Content Connections to ARSJ Teaching

In the previous chapter, I explored participants' experiences with opportunities to learn ARSJ STEM teaching. In doing so, I demonstrated how participants' levels of reflexivity and connections to agency, as well as their developing conceptions of ARSJ STEM teaching practices, shaped their engagement with and success in taking up such opportunities. In this chapter I present analyses of participants' perceptions of STEM content connections to ARSJ teaching practice. Specifically, I attend to how participants spoke about the extent to which they viewed their respective STEM content areas as connected to elements of ARSJ teaching practice. I begin the chapter exploring residents Stella and Kendall's perceptions of ARSJ STEM teaching and how these views made their way into practice. Then, I turn to data related to interns Aaron and Iris's perceptions of ARSJ mathematics teaching, as shaped by their experiences with their attending teacher, Matthew, as well as their university coursework, which served as a vital and complimentary component of their pre-service training. I conclude the chapter by offering insights into takeaways for the teacher education community and foreshadow important implications of the work. Below, I present a portion of the key linkage chart that corresponds to the findings presented throughout the chapter:

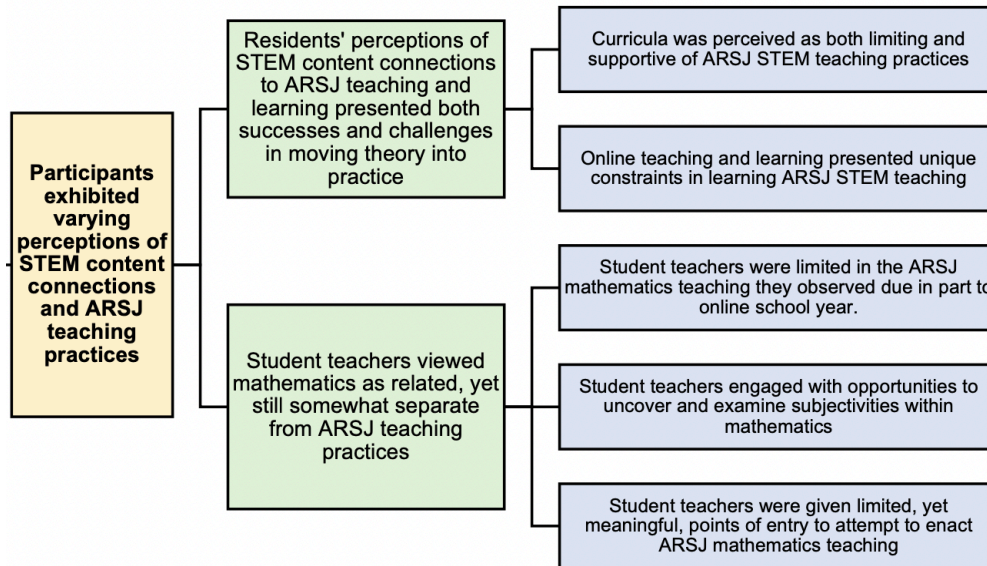


Figure 6-1 Chapter 6 key linkage chart segment

**Residents’ Perceptions of STEM Content Connections to ARSJ Teaching Practices:
Successes and Challenges in Moving Theory into Practice**

Given the opportunities to learn ARSJ STEM teaching practices discussed in the previous chapter, I now turn to how such opportunities may have shaped participants’ perceptions of STEM content connections to ARSJ teaching practice. Particularly, I explore how participants viewed their respective STEM content as connected, or not, to elements of ARSJ teaching practice, as well as how such perceptions extended into residents’ practice. Although I assert that disciplinary STEM concept and skill learning must be at the heart of ARSJ teaching practices, data suggests TTS participants did not always see the two as connected, instead speaking about the challenges of connecting disciplinary knowledge and skills to elements of ARSJ teaching practices. Throughout my analysis, I found variations on how residents viewed or thought about STEM content as related to ARSJ teaching and learning, with both challenges and successes along the way.

Residents Stella and Kendall exhibited varying degrees of STEM content integration in their perceptions of ARSJ teaching practice, as evidenced by interview and classroom observation data. Across residents, I found the more the resident thought about ARSJ teaching practices as a natural extension of STEM content, or a lens through which to view all pedagogical decisions, the more likely they were to be observed in their practice. Furthermore, it appeared that participants who successfully integrated STEM concept and skill learning with elements of ARSJ teaching practice seemed to become more proficient with each integration and appeared more likely to integrate disciplinary content and skills with ARSJ STEM teaching practices than those that struggled to do so. Since I am working with a small sample size, I choose to present these findings as cases. I will first explore the case of Kendall, who exhibited a somewhat limited sense of integration in her perceptions of STEM concept and skill learning and ARSJ teaching practice. Then, I turn to Stella who exhibited a more integrated and sophisticated sense of integration. As will be demonstrated throughout the chapter, I found that for Stella, her success at integrating ARSJ teaching practices and engineering appeared to encourage more integration. For Kendall, her struggles to integrate ARSJ teaching practices into her science teaching appeared to diminish her attempts at doing so.

Kendall: Limited but Meaningful Connections with Room for Improvement

Kendall viewed connections between physical science concepts and skills and elements of ARSJ teaching and learning as limited. Although she made connections between science and ARSJ teaching practice, she viewed the two as largely separate, as exemplified in both her interviews and her teaching. However, as will be exemplified through data excerpts below, Kendall did display a desire to incorporate more elements of ARSJ teaching into her practice, yet she did not always possess the pedagogical knowledge to do so. For Kendall, numerous

challenges arose when attempting to move theory into practice. For example, although Kendall was given relative freedom to adapt curricular materials as she saw fit, she still felt restricted by the curriculum laid out by the district and said was looking for ways to “integrate [ARSJ teaching] regularly that doesn’t feel like **sucking out time**” (Interview, 2/4/21, emphasis added). Such feelings about the curriculum could have been tied to the amount of time she afforded herself to *critically examine STEM curriculum*. As previously stated in earlier chapters, Kendall did not always fully engage in opportunities to examine and adapt her science curriculum with attending teacher educators. Feeling as though ARSJ teaching detracts or ‘sucks out time’ from the curriculum exemplifies why I characterized Kendall’s perceptions as limited in scope and opportunities to integrate. Incorporating ARSJ-specific topics was viewed as a challenge and not necessarily a natural extension of the work she carried out with students. When asked to think about what it means to teach in ARSJ ways, Kendall spoke in general terms about the “achievement gap”: “working to close that achievement gap, knowing that the achievement gap exists, and it exists because of oppression and that exists because of the lack of number of teachers that are teaching these students” (Interview, 10/20/20). Here, Kendall appears to be engaging in somewhat of a root-cause analysis if I might borrow language from Stella’s human-centered engineering and design course. Kendall makes connections between the achievement gap – perhaps more appropriately known as an opportunity gap or receipt gap, referring to the resources and opportunities presented to or received by students (cf., Chambers, 2009) – and the lack of teachers, specifically pointing to quantity (*lack of number of teachers*) and not necessarily quality. Based on this comment, perhaps Kendall viewed her role in TTS as working to close the perceived achievement gap simply by being present, not necessarily by making connections between the development of STEM concepts and skills with the pursuit of

educational equity and justice for her students. In this instance, there appeared to be an opportunity to connect Kendall's perception of an opportunity gap with STEM learning opportunities designed for students. Such connections would have not only strengthened Kendall's planning and implementation of lessons by considering more meaningful connections to students' interests, identities, and lived experiences (i.e., *drawing on students' cultural knowledge and capital*), but it would have also perhaps strengthened students' sensemaking of STEM concepts and skills, allowing them to engage in more disciplinary ways throughout her class.

When asked to think about what it means to be an ARSJ *science* teacher, Kendall emphasized the importance of representation and the ways in which it supports students' ability to see themselves in science, drawing strong connections to the ARSJ teaching practice of *developing disciplinary identity*. Kendall mentioned ARSJ *science* teaching was about "giving role models of BIPOC people in science" (Interview, 10/20/20), as well as those from intersectional minoritized groups, such as women and members of the LGBTQ+ community. According to Kendall, "representation in science" is so important because "it's really hard to see yourself in a field that no one looks like you" (Interview, 2/4/21). Such ideas about representation also supports students in reimagining who does science by engaging in *learning opportunities that question the status quo*. However, when moving theory into practice, Kendall sought out or discovered few opportunities to incorporate BIPOC figures into her curricular materials, further demonstrating the limitations she faced in *critically examining curricular materials* and adapting as necessary. Out of 87 classroom observations, only 3 lessons spanning 8 class periods highlighted BIPOC figures as doers of science, as depicted in Table 6-1 below:

Lesson	Class Periods	Description
1	9/24/20 9/28/20 9/29/20 10/6/20 10/7/20 10/8/20	Students chose two BIPOC scientists and engineers from a curated list to learn about through readings and videos over the course of several lessons. In these class periods, students were asked to fill in a graphic organizer with information they gather about each person.
2	10/28/20	Students engaged with a Van de Graaff generator simulation where a White woman straight blonde hair was depicted placing her hand on the machine with her hair sticking straight up. Kendall presented students with a picture of a Black woman doing the same thing and discussed how this might look different given different hair textures.
3	2/10/21	Students learned about the COVID-19 vaccine development and efficacy over several lessons. In this lesson, Kendall showed students a video of the Black woman scientist who helped develop the vaccine.

Table 6-1 Curricular instances of BIPOC representation, physical science

In each instance described above, Kendall found small ways to incorporate BIPOC representation into physical science curricular materials. The most extensive example of this is in the first lesson in Table 5-1 (above) where students chose two BIPOC scientists and engineers to learn about and complete a graphic organizer with the information they gathered. Although students were not asked to synthesize information gathered from the readings beyond completing the graphic organizer, Kendall nevertheless felt proud of the work she carried out in designing and curating materials for students:

I feel proud of the work that I did to find all of these different scientists and engineers. I mean, **I worked my butt off trying to find people and find good readings that I thought the kids could do and trying to find ways that they might feel connected with these people**, trying to have them work in groups to come up with people so that they're closer to people they want to learn about (Interview, 10/20/20, emphasis added).

In the remarks above, Kendall highlighted an important point about creating and adapting curricular materials. Not only was she looking to create relevancy for her students, but she was also looking to create materials that did not currently exist. The time and energy required to add

and create materials is time away from other necessary planning and instructional tasks. Thus, it is perhaps unsurprising that Kendall found only a few areas in her curriculum to adapt materials and create more relevancy and representation for students. Furthermore, the lack of appropriate material forced Kendall to choose between “*working [her] butt off*” to create or adapt materials and presenting her students with relevant BIPOC figures in STEM fields.

The second lesson depicted in Table 5-1 (above) was the only instance where Kendall adapted existing curricular materials to become more relevant and representative of students’ interests and identities, relating to ARSJ teaching practices of curricular adaptation and *drawing on students’ cultural knowledge and capital*. In the original curricular materials, a blonde-haired White woman is seen touching a Van de Graaff generator with her hair sticking straight up to demonstrate the static electricity transferred through the machine (below, right). Kendall critically examined these materials and identified this as a gap and an opportunity to increase BIPOC representation in the curriculum. Instead, Kendall showed students a picture of the White woman alongside a Black woman (below, left) engaging in the same activity (Classroom Recording, 10/28/20):

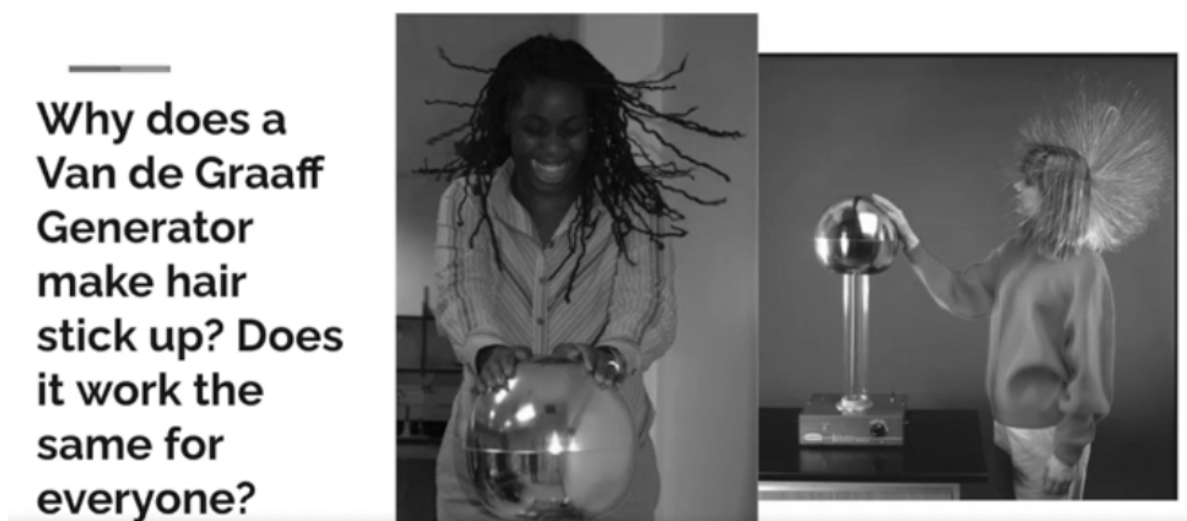


Figure 6-2 Van de Graaff generator slide, physical science, 10/28/20

Kendall's simple inclusion of a person of color using the machine opened an opportunity for students to see themselves "doing science" within the curriculum. Furthermore, the imagery initiated a discussion around different hair types and textures, allowing students to draw on their expertise around both scientific concepts and hair. The data exemplar below depicts Kendall's ensuing conversation with students:

1 Kendall: What are we noticing?

2 Student 1: The Van de Graaff generator is making both of their hair go up.

3 Kendall: [nods] It's making both of their hair go up. Right on. What else do we notice?

4 Student 2: Is it using static energy?

5 Kendall: Oh, maybe they're both using static energy. Okay, thanks. Do we notice any

6 difference in what's happening between these two pictures? [reading the chat] Yeah,

7 their hair strands are rising. Is there any difference though?

8 Student 1: I don't really know if this is a difference, but the first girl has both of her

9 hands on it and the second girl has one of her hands on it.

10 Kendall: Okay, so maybe something about two hands versus one.

11 Student 3: The one lady with two hands on the thing, her hair is more put together,

12 she has like locs, and the one who has one hand, she has more like individual strands.

13 Well, I wouldn't say individual, but she has more of a scattered...

14 Kendall: Yeah, so I would say that the Black lady on the left, it actually looks like her

15 hair is in braids. [reading the chat] So [student 4] is saying they both have different

16 types of hair or hair textures. So, what could different hair textures, why would that

17 affect anything?

18 Student 5: I feel like it would take more force, or more energy, to lift the braids

19 because they're probably heavier because there's a lot more hair in each one, whereas
20 with the girl on the right, the individual strands are a lot lighter and so it takes less
21 force to make them go straight up.

22 Kendall: Okay, so maybe it has something to do with the weight of the hair.

23 [Student 6], when you touched it, what did it do to your hair?

24 Student 6: I was looking like a porcupine.

25 Kendall: [laughs] Okay, and how would you describe your hair texture, if you don't
26 mind?

27 Student 6: Right now?

28 Kendall: Or, I guess, when you touched it?

29 Student 6: It was pretty soft. I didn't put anything in it.

30 Student 1: I was going to say, I don't think it depends on hair texture, I think it
31 depends on hair style because the girl on the left, her hair is in locs, but I feel like if
32 she put it in an afro or if she combed it out, then it probably would be easier for the
33 static electricity to lift it up. And vice versa for the girl on the right, I feel like if she
34 had her hair in a ponytail or a hair style then it wouldn't have worked as well.

35 Kendall: [points to her hair down] So, why didn't it work for me?

36 Student 6: You probably had some type of grease in your hair that weighed it down.

37 Because the girl on the left, because she has dreadlocs, her hair is kind of weighted

38 because those dreads have a little bit of weight other than little strands of hair

(Classroom Recording Transcript, 10/28/20).

Kendall began the conversation above by asking students what they noticed about the two pictures. Students then responded by saying there are differences between the number of hands

on the machine, but both sets of hair are standing straight up. Kendall continued to ask probing questions, and it was not until Line 11 where a student mentioned the word “locs” that other students began talking about differences in hair texture and how this might affect interactions with the Van de Graaff machine. Interestingly, but perhaps unsurprisingly, students never mentioned race, instead referring to each woman as “the one on the right” or “the one on the left.” In line 14 Kendall brought up race by identifying the woman on the left as “the Black lady,” yet students did not choose to take up this language throughout the rest of the conversation. It could be the case that students did not yet feel comfortable calling out race at this point in the year with a White teacher, even though Kendall modeled this language for them. However, I would like to point out lines 14 and 15 where Kendall attempts to correct students’ use of the term “locs” by stating “I would say that the black lady on the left, **it actually looks like her hair is in braids**” (Classroom Recording Transcript, 10/28/20, emphasis added). Although most students did not acknowledge this language and, instead, continued to use “locs” and “dreadlocs” when referring to the picture, Kendall could have further centered students as experts in this space and adopted the language they used when referring to the picture throughout the discussion. Nevertheless, the discussion depicted above garnered a high degree of student involvement relative to other class sessions with six students participating, most of which utilized the microphone to share out. This type of student engagement demonstrated how Kendall was able to capitalize on students’ interests, identities, and lived experiences while engaging in science concept and skill learning. Throughout the discussion, students made complex claims about the relationship between weight or mass and electric force, creating strong connections between disciplinary knowledge and personal expertise. By providing relevant representation

and positioning students as experts, Kendall opened space in the curriculum to enact meaningful ARSJ STEM teaching practices.

Although Kendall integrated hair texture and electric force, as the school year progressed, such curricular adaptations were few and far between. The last instance where this comes up in her practice is in February 2021 where she designed a lesson that spanned a few class periods focused on the COVID-19 vaccine efficacy and development. The add-on lesson consisted of many slides explaining what a virus is, how our body develops antibodies to fight off infection, and how misinformation about the MMR vaccine caused many families to choose not to get their children vaccinated. In the process, Kendall touched on sample size, as well as graphical interpretations. On the last day of the lesson, Kendall showed students a video of the Black female scientist that helped develop the COVID-19 vaccine, yet students were not asked to engage with this information beyond watching the short clip (Field Notes, 2/10/21). The add-on nature of this lesson could have been what Kendall was referring to when she mentioned wanting to find ways to incorporate ARSJ teaching without “sucking out time.” Although discussing vaccine science was a relevant and important topic, perhaps the time and energy it took to build such a lesson could have been used to adapt more existing curricular materials, as seen in the Van de Graaff generator example discussed above. Furthermore, the disconnected nature of the video of the Black female scientist to science concept and skill learning makes it difficult to characterize this instance as ARSJ STEM teaching practice. However, this instance represents an attempt at incorporating more relevant materials for students, which could be used as a catalyst for further critical examination and adaptation of curricular materials in the future.

Challenges in Moving Theory into Practice

Given the lesson examples described above, it became clear that Kendall wanted to incorporate elements of ARSJ science teaching practice, yet she did not always know how to integrate such elements in her practice. In the previous chapter, I discussed how Kendall struggled with and resisted feedback from attendings. Analyses across multiple data sets in the study suggest that Kendall's struggles were due in part to her stances towards learning as a teacher, and in part due to her position as a first-year teacher in the throes of a virtual school year teaching through a global pandemic. In interviews, Kendall spoke about the challenges she faced when considering how and when to talk about issues such as racism in her science class, including the nature of online schooling. Given the virtual school year, students submitted their work online and were often given an extra day or two beyond the class period to do so. In the interview excerpt below, Kendall described the challenges of determining when and how to bring up ARSJ topics with students, given that she was not often able to review their work in real-time, using students' annotation assignment as an example:

I'm still working on trying to find that line of what things do I address and what things do I kind of wait until you have more of an idea of, more prior knowledge in order to talk about this. I think it's hard. I was thinking with their annotations, right, that some of them put things like, oh, this, this happened back when racism was a thing. **And I was thinking that I would have really liked, if we were in a real setting...I would have loved to kind of have that break off conversation and talk about that, but it's hard when I can't see it until two days later, then I'm like, 'oh dang.'** So, yeah I would love to have more of those kinds of conversations as they come up, but **in this virtual setting, it's a little bit difficult to do so** (Kendall, Interview, 10/20/20, emphasis added).

Here, Kendall talked about her desire to have more conversations with students about topics like racism, but she mentioned a few challenges in doing so. First, she found it challenging to address topics without knowing about students' prior knowledge, which could have been her way of saying she was not sure how to approach topics with students before developing meaningful relationships, which was significantly more difficult to do in an online learning environment. Secondly, she found it challenging to address topics when she was not able to review information in the moment. Instead, she would often receive assignments a few days after she assigned them to students in class, at which point the class had already moved on to the next lesson or topic. To counteract this, Kendall could have adjusted her assignment timelines, or she could have had students share out summaries at the end of class to serve as formative assessments and help her shape conversations with students, moving closer to *responsive evaluation and assessment measures*. Lastly, Kendall mentioned the virtual setting as a constraint in addressing such topics with students. As aforementioned, the virtual environment made it difficult to develop relationships with students in the same way we might expect in person. At the very least, it took longer to form relationships than in an in-person setting. The virtual learning environment also precluded Kendall from circulating the room to briefly read what students wrote and respond in-the-moment. However, as mentioned above, there were small changes Kendall could have made to her instruction that would have allowed her access to student work in a timelier manner.

In analyzing the challenges Kendall faced, it is important to again note the opportunities to improve her online teaching practice that she rejected. First, Kendall was offered the opportunity to work on her curriculum alongside TTS attending teacher educators while receiving compensation in the form of payment for her time and independent study credits through the university. Towards these efforts, I met with Kendall multiple times throughout the

summer leading up to the start of the 2020-2021 school year and encouraged her to think about curriculum mapping and lesson planning. Efforts to engage Kendall in this work were met with requests to postpone meetings (Personal Communication, 7/17/20, 8/12/20) and overall feelings of being overwhelmed. I then took it upon myself to start mapping and lesson planning, though these materials were largely not taken up by Kendall (see Chapter 5). Hence, although Kendall described many challenges to incorporating ARSJ teaching practices into her science concept and skill teaching with students, suggestions to improve her practice were often met with resistance. These findings suggest implications for TTS model features, which I will expound upon in Chapter 7.

In addition to wanting to approach topics like racism with students, Kendall also acknowledged a desire to redesign curricular materials and “find more seamless ways of highlighting Black and Brown scientists, not just in the first unit, but throughout” (Interview, 2/4/21). Finding more seamless ways to highlight BIPOC figures in the curriculum requires time and energy when they are not initially included in materials. As Kendall mentioned, she wanted “to have more time and energy to really focus on building out an inclusive curriculum, building out more projects or projects in general” (Interview, 6/24/21), which demonstrates her commitment to learning about and developing ARSJ STEM teaching practices, this did not happen during the school year. Although Kendall engaged with additional supports such as coaching, it still did not appear to be enough to allow her the time and space to focus on curriculum throughout the school year. Again, this could have been due to her stances towards learning as a teacher or resistance to feedback, as well as the pressures she felt as a first-year teacher teaching online. However, Kendall did acknowledge there was room to improve her curricular planning, adaptations, and implementation, stating, “there's a lot of growth I see for

myself in terms of the curriculum stuff' (Interview, 6/24/21). Furthermore, Kendall appeared to widen her definition of ARSJ science teaching practice in considering changes she might make to her curriculum in the following year, including not only representation, but also addressing bias in the scientific community:

Science is biased and I've been reading this book of a Black woman physicist who is talking about just all the biases in physics, and how of course race is tied to everything ...from the things we name things, to who gets access to do physics or particle physics, in general. So, I don't know, educating students about that, but also showing that just because things have been done this way does not mean they have to be done this way, or should be done this way (Interview, 6/24/21).

In the interview excerpt above, Kendall hints at both *critically examining the curriculum* and *designing learning opportunities that question the status quo*. In this sense, Kendall appeared to exhibit knowledge of what ARSJ STEM teaching practices she would like to learn about and enact, as well as set goals for herself for the following school year. Since incorporating all these elements into the 2020-2021 virtual school year proved challenging, it was hopeful to see that Kendall was thinking about such things as we moved out of the school year and into the summer transitional period before the following academic year began. Although Kendall referred to her commitments to ARSJ STEM teaching practice in interviews, the challenges she faced in moving theory into practice could be indicative of her commitment to improve on her practice, or her knowledge of how to do so. It could have been the case that Kendall was committed to improving on her practice – she did, after all, enter TTS residency with knowledge of the types of support she would receive – yet she did not fully know how to translate feedback into practice.

Not fully knowing how to take up feedback could have translated into the resistance and defensiveness I observed in relation to engagement in and uptake of learning opportunities.

Stella: Teaching Engineering While Wearing ARSJ-Colored Glasses

Stella made it apparent through interviews and observations that she viewed her role as an engineering teacher through a lens of ARSJ teaching practices. Throughout the year, Stella spoke about ARSJ “as a lens” through which she approached her work, stating: “It’s a way that you look at things, it’s a way that you act. **There’s not a thing that you do, but a way that you do everything**” (Interview, 11/2/20, emphasis added). Stella went on to mention that ARSJ engineering teaching is about the way that she both does things and see things, meaning that to fully achieve this, all aspects of her “practice need to shift in that direction, not just one, not just the content, not just relationships with the kids not just reflection on practice but all those things” (Interview, 2/16/21). Stella further emphasized that embedding ARSJ teaching practices into her development of engineering concepts and skills with students requires that “it has to be a part of everything you do” (Interview, 6/29/21). One of the ways in which Stella perceived engineering concept and skill learning as integrated with ARSJ teaching practices was through thinking critically about engineering as a discipline. In doing so, she not only explained her own perceptions, but also how she thought about students’ perceptions of STEM. In working to build students’ identities as engineering doers and sense makers, she also considered how bias shows up in every aspect of the discipline:

In STEM particularly I think that **there’s an objectivism that comes with STEM** where it’s like we’re dealing with facts or numbers or things that are non-debatable and outside of the realm of the world. And so, they’re viewed that way, which is very problematic. **I don’t want students to think that STEM is beyond those**

issues and then have them be interested in something and realize a reality when they enter those spaces later in life that's different. Like, **I don't want to teach students that there isn't bias in engineering because there absolutely is in every, every way** (Interview, 11/2/20, emphasis added).

In the data excerpt above, Stella described how a perception of STEM as objective can be problematic. Particularly, as she points out, if engineering and related fields come across to students as objective, this is not an accurate or realistic description, nor is it what students might come to expect if they choose to enter a STEM field later in life. Engaging students in thinking about the realities and subjectivities of STEM spaces is important in not only preparing students to participate, but also to change the ways disciplines operate to include or exclude individuals from minoritized backgrounds. Such perceptions connect to the following ARSJ STEM teaching practices:

1. Design learning opportunities to question and reimagine the status quo.
2. Develop disciplinary identity.
3. Critically examine curriculum.

Stella returned to the idea of 'objectivism in STEM' throughout the year, continuing to think about the connections between engineering concept and skill learning and ARSJ teaching practices:

I also think that in my practice it's **recognizing the work that engineers and designers have done that is very socially just**, like we talked some about the Flint water crisis, we've talked about a few other topics where engineers are doing the work of social justice and listening to communities and all these things. **And the flip of that I think is also recognizing the faults of engineers or even**

engineering, like that mindset around it. You know, there's a whole thing of STEM objectivism, the idea that there's no bias involved because it's data... And so, trying to pull away from that too and recognizing some of the specific ways that engineering might not be... **I don't want to present it as a perfect field, or like a solution to everything field, and how bias can be involved with that.**

Like we talked about facial recognition and how that is, in part, a problem that is biased code, right, and biased machine learning. I think those things are really critical to socially just engineering teaching (Interview, 2/16/21, emphasis added).

Here, Stella described how she does not mean to present engineering as a perfect field. Rather, she intends to uncover a sense of false objectivity present within all STEM fields. In particular, she mentioned there is a way to talk about engineering that recognizes the socially just work being done, while also recognizing that not everything in the field is inherently good.

Recognizing bias in a field that is typically viewed as objective is a critical part of ARSJ engineering teaching, as she pointed out. Furthermore, engaging students in such critical examination supports a questioning and reimagining of the status quo within STEM fields.

Stella's engineering curricular materials embedded elements of ARSJ teaching practice through both the focus of design projects (Table 6-2) and the topics of her modeling segments in class (Table 6-3). Stella's design projects *positioned students as experts and agentic changemakers, drew on students' cultural knowledge and capital* by centering on students' communities both in and out of school, and supported students in *developing engineering tools to address community concerns*. The first two design projects focused on wellbeing and belonging at Fairfield, working to provide solutions to a fractured communal feeling while completing school online throughout the 2020-2021 academic year. As depicted in Table 5-2 (below), the

second design project built off the first and included not only wellbeing and belonging, but also community health and safety, and school preparedness and organization. Within this design, students had the choice to focus on Fairfield online schooling or their home environment. Lastly, students focused on designing solutions to support themselves and others in being successful the following school year (2021-2022). At the time, students did not know whether they would be attending school in person or online, thus they were given the freedom to design for either potential.

Design	Problem Focus
1	Wellbeing and belonging at Fairfield
2	Wellbeing; Belonging and socializing; Community health and safety; School preparedness/organization. Setting: Fairfield online schooling OR in your home
3	How can we support ourselves and other school community members in being “successful” in school in the fall?

Table 6-2 Problem foci for design projects, human-centered engineering and design

The iterative nature of the curriculum reflected Stella’s focus on development of disciplinary practices and tools with students. Not only did students learn about human-centered engineering and design tools on a deep level, but they also did so while engaging in meaningful community-focused problem spaces, drawing strong connections between engineering concept and skill learning and ARSJ teaching practices.

Although the larger problem spaces addressed community issues and concerns, explicit attention to issues of social justice was seen most prominently in the modeling segments of Stella’s class. As mentioned in chapter 5, the spiral nature of the engineering curriculum allowed Stella to introduce or refamiliarize students with an engineering and design tool through whole-class instruction before students worked in teams to implement on their own. Although each design cycle was place-based and focused on the school or class community, it did not always explicitly touch on themes of social justice. So, Stella used the modeling portions of class as an

opportunity to incorporate such themes. Stella considered how this differed from the year prior, stating:

My teaching practice has changed. **I think I’m doing a better job of bringing social justice issues into the classroom** and talking about those with students in a way that we didn’t really talk about last year as much, or maybe as consistently...**I try to bring in issues of social justice as much as possible, particularly in the modeling that we do in the class.** I like to bring in topics that might be new to students or things they might have a connection to (Interview, 2/16/21).

Stella recognized that her practice had improved from the year prior, and she saw modeling as an opportunity to tie in issues of social justice. Table 6-3 (below) outlines each design tool modeled throughout the class and the topic used to demonstrate the tool with students. As Stella indicated in her remarks above, most modeling topics were centered on issues of social justice, such as ventilator shortages and the Flint water crisis. Modeling was more prominent in the beginning of the school year when students were new to the curriculum and learning about each tool for the first time. As the school year progressed and students used the tools multiple times, instances of teacher modeling became more infrequent. Instead, modeling was used to provide additional support or serve as a content refresher for students.

Date	Design Tool Modeled	Topic
9/30/20	Root Cause Analysis	Toilet paper shortage in the pandemic
10/7/20	Problem Scoping	Facial recognition software/AI bias
10/16/20	Data Collection and Survey Design	Circulation of misinformation
10/21/20	Data Analysis	Ventilator shortage
11/11/20	Public Communication	Shark Tank/science fair videos
12/9/20	Root Cause Analysis	Classroom mobility and accessibility
12/16/20	Problem Scoping	Flint water crisis
1/13/21	Data Collection	Flint water crisis
2/24/21	Prototyping	Lunchbox designs

4/9/21	Data Collection	Observing people along a riverwalk
6/9/21	Public Communication	Video recording of teacher presenting

Table 6-3 Design tool modeling topics in human-centered engineering and design curriculum

Since Stella emphasized bias within engineering as a desired topic for discussion with students, I use the space below to describe Stella’s use of ‘facial recognition software bias’ (Table 6-3, above). Problem scoping is a human-centered engineering and design tool aimed at categorizing knowns and unknowns about the problem space in efforts to define a problem before designing a solution. This practice allows students to take stock of what they know, as well as what more they need to learn to better understand the space within which they are designing. Stella began introducing students to scoping with a video on racial bias within artificial intelligence (AI) software, which explained how AI programs often mistake Black women for Black men or have trouble identifying people of color in general. After displaying this video, Stella had students record what they knew about this problem based on the video, as well as what questions they still had after watching. Stella recorded students’ thoughts in the table below (Figure 6-3) and then guided students in categorizing each statement as either a known or an unknown and as logistical or social factors.

Scoping Table		
Questions/Statements	Known or Unknown?	Social Factor or Logistical Factor?
Detroit Police Department is using facial recognition software	Known	Logistical Factor
Facial Recognition Software has been shown to have bias based on race, gender, and age	Known	Logistical
How do Detroit residents feel about facial recognition software?	Unknown	Social Factor
How often is facial recognition software used in police cases?	Unknown	Logistical Factor

Figure 6-3 Scoping table example, classroom recording, 10/7/20

This example of Stella’s instruction demonstrates her incorporation of 1) *designing learning opportunities to question and reimagine the status quo*, 2) *developing engineering tools to*

address community concerns, and 3) *critically examining curriculum*, all while rooting the lesson in engineering concept and skill learning.

Although Stella made many successful attempts to incorporate ARSJ teaching practices into her engineering instruction with youth, she viewed her modeling segments and project work as almost separate entities when it came to social justice:

I'm not sure how well social justice issues integrate directly into project work (they're starting to do so more now), but we discuss issues of justice in our modeling. All of the work centers on the community and students are guiding their own project work... [social justice] discussions are happening, but action is questionable (Journal Entry, 12/14/20).

In the journal entry above, Stella stated that although she felt social justice was integrated well into her modeling, she did not view project work in the same way. She mentioned that project work *centers on the community*, and although this is an ARSJ STEM teaching practice as defined in this dissertation, Stella did not view it as such. Instead, data suggests that Stella viewed explicit ties to social justice topics as work centered on ARSJ STEM teaching, yet more implicit practices, such as community-centric projects, were less so. Thus, although Stella stated that she viewed ARSJ as a lens through which to approach all engineering pedagogical decisions, it appeared that her view became somewhat more narrowed when it came to implementation with youth. This view has important implications for how we both present and develop conceptions of ARSJ STEM teaching practice with pre-service and beginning in-service STEM educators. If such a view of separation is commonly held, perhaps more so by STEM educators than other disciplines, then more work needs to be done to draw explicit connections between community and student-centered work and that of ARSJ STEM teaching practices. Without discounting the

importance of explicit STEM content connections to issues of social justice, ARSJ STEM teaching practices encompass more than curricular adaptations that include such themes.

Uncovering Subjectivity in STEM: Student Teacher Experiences and Perceptions

Throughout their time as pre-service teachers in TTS, Aaron and Iris learned a great deal from Matthew about ARSJ *mathematics* teaching. Because STEM disciplines are historically portrayed as objective or acultural, it is sometimes difficult to find connections in ways that are perhaps more easily apparent for other content areas, such as English or History. As Aaron pointed out, “math is a little bit trickier” (Interview, 12/10/20). One of the lessons he learned from Matthew, however, highlighted not only the connections between mathematics concept and skill learning and ARSJ teaching practices, but also challenged the seemingly objective nature of mathematics:

I always think about when [Matthew] told the students, ‘Even though people say numbers never lie, numbers can definitely lie.’ And I remember him saying that to them because **it made me think about it in terms of how we use math to convey certain messages** like incarceration rates or crime rates per, you know, race, by race or ethnicity, and what those numbers really communicate to people and the types of mindsets they might shape and what that might mean for social injustices or a socially just society. So, **I do think there are a lot of connections if you look for them**, or if you take the extra step of thinking like, oh, how can I connect this to this issue that's happening right now? (Interview, 12/10/20, emphasis added)

Observing Matthew’s instruction started to create connections for Aaron between mathematics content and ARSJ teaching. As Matthew pointed out to Aaron, *numbers can lie*, in the sense that

they can be used to convey potentially harmful messages about minoritized groups and perpetuate stereotypes. This idea starts to challenge the notion that subject-matter dealing in numerical representations, such as mathematics, is void of human influence. Matthew's conveyance of this to his student teachers set the tone for how he viewed mathematics and provided a lens through which Iris and Aaron could view mathematics teaching. Aaron went on to say that there are connections between mathematics and social justice issues *if you look for them*. This implies that such connections are not always explicit or readily accessible to teachers and students, further highlighting the importance of opportunities to learn within TTS model that make explicit connections between STEM concept and skill learning and ARSJ teaching practices. As Aaron pointed out in the previous chapter, who and what you observe as a student teacher matters. Had he and Iris been placed with someone who did not view mathematics in this way, or someone who perhaps did not make these ideas explicit to both students and pre-service teachers, we run the risk of perpetuating potentially harmful ideas about STEM objectivity, "which isn't going to end the cycle" of inequitable practices (Aaron, Interview, 12/10/20).

In addition to interrogating objectivity within mathematics, Matthew also demonstrated to student teachers his commitment to representation of diverse and underrepresented groups in math content presented to students. As Iris pointed out:

I feel that math has always been very White centric and it's as simple as sometimes just calling or naming really significant mathematicians that weren't necessarily, usually White men specifically in math, you know, being able to recognize other people that your students could relate to (Interview, 4/20/21).

Here, Iris called out mathematics as a traditionally White-centric enterprise and noted that something as simple as calling out mathematicians from other backgrounds can support students

in seeing themselves in the curriculum, drawing connections to *designing learning opportunities to question and reimagine the status quo*, and *developing disciplinary identity*. Similarly, in the interview excerpt below, Aaron pointed out the ways in which he observed Matthew attending to representation and actively working against stereotypical images of successful mathematicians as White and male:

I guess specific to math, obviously there's a lot of just old White men that are held up as the brightest mathematicians. But, I know **one thing Matthew tried to do is include representation in terms of just either Black female mathematicians, or people that usually aren't held up as the image of a mathematician**. And also, just working with students to help them be confident in their own math abilities, especially if they're part of a demographic that's not usually seen as being successful in math, or I guess anyone other than a White man, is I think specific to math. **There's obviously a lot of stereotypes in math in terms of what a mathematician looks like, so making sure that's not the case in your classroom is important** (Interview, 4/27/21, emphasis added).

Here, Aaron pointed out that he observed Matthew including underrepresented individuals and groups in his mathematics curricular materials, which was representative of *critically examining curriculum*, as well as *designing learning opportunities to question and reimagine the status quo*. Because students, and society writ large, are accustomed to seeing “old White men” as synonymous with math, it was important for Matthew to not only widen his students’ perspectives, but also that of his student teachers. In this sense, Matthew demonstrated his commitment to both student and teacher learning, creating more relatable and relevant curricular materials in the process. Furthermore, Aaron acknowledged that representation matters and can

affect students' opportunities to see themselves as someone who does math, connecting to *developing disciplinary identity*. In doing so, Aaron also acknowledged the teacher's role in perpetuating stereotypes within math, or breaking that cycle, as he stated *making sure that's not the case in your classroom is important*.

Based on his interviews discussed thus far, Aaron thought about how to integrate ARSJ practices into his own mathematics teaching. However, when attempting to move theory into practice, Aaron was faced with challenges in integrating ARSJ themes into his teaching of mathematics. For example, in the data exemplar below, I asked Aaron a follow-up question to his description of Matthew's emphasis on representation of underrepresented groups in the mathematics classroom:

Rachael: Are there any examples from your practice where you felt like you were doing some of that work that you're talking about?

Aaron: I wish that there were more. **I feel like for my practice specifically, nothing really explicit ever came up like that.** And it's hard because I want to say that I did like make a conscious effort to include more students in conversations, like if one or two were taking over, trying to call on students that never really talked because they might not be super confident in, you know, just math in general. **If I could look back and assess how well I did, that would be something I think would be beneficial** (Interview, 4/27/21, emphasis added).

Here, Aaron talked about how he wishes there were more examples of integrating representation and overall student participation in his lessons. He mentioned that *nothing explicit* came up, although it would have been helpful to *assess how well he did* with integrating such a practice. This statement highlights the need for perhaps more self-assessment or explicit attention to ARSJ

STEM teaching practices in evaluation and assessment measures for pre-service and early career teachers. Matthew's classroom appeared to be rich with opportunities to learn about ARSJ mathematics teaching, yet such practices were not fully taken up by student teachers. This could be indicative of student teachers' placement in their trajectory as educators, attempting to balance and integrate multiple pedagogical tools and skills at the same time. Furthermore, student teachers have limited autonomy and agency when designing and enacting instruction in an attending teacher's classroom. Similarly, attending teachers have multiple, sometimes competing, interests happening in the classroom at any given time and may not have the capacity to critique or iterate upon every action a student teacher takes. However, the extended, embedded, and place-based features of TTS model perhaps make it more likely that student teachers, and eventually residents, will receive the support needed to not only learn about but eventually integrate aspects of ARSJ teaching practices into their STEM teaching.

Although limited in autonomy and agency as a student teacher, Iris was still able to incorporate small actions in her practice to move towards the ARSJ STEM teaching practice of *designing learning opportunities for students to question and reimagine the status quo*, as well as *critically examine curriculum*. Drawing on Matthew's work to increase representation in his mathematics curricular materials, Iris reflected on how she attempted to do the same:

When it came to lesson planning, this is one example, it was really small thing. The slides that I used they were pre-made slides and they were a math-y type of theme of slides, and **on the slides the only human figure that showed up was a White man, and so being able to change just something as small as that can make a difference** (Iris, Interview, 4/20/21, emphasis added).

In the data excerpt above, Iris demonstrated how she viewed her curricular materials through a critical lens and adapted them to reflect students' identities and interests. As she pointed out, a White man was the only human figure that appeared on the slides, further reifying historical and contemporary stereotypes of who "does math." Iris's small adaptation to course materials potentially provided a counternarrative for students to relate to as they worked with the slides. Moving this a step further, Iris could have also made this explicit to students, highlighting the steps she took to ensure students saw themselves in images of mathematicians and developing tools to recognize, question, and reimagine the status quo.

ARSJ STEM Content Connections in University Coursework

In addition to learning from their attending teacher, both Aaron and Iris found connections between mathematics concept and skill learning and ARSJ teaching practices through their methods courses on the university campus. According to Iris:

One realization I had recently was from our methods course. We explored a book that had different math problems that were related to social justice and the one I had read through was specifically about the likelihood of somebody being Black being arrested for marijuana use versus somebody being White and things like that. I think **it really showed me how much more social issues actually can be implemented into math** because I definitely say **beforehand, my mindset was like, oh it's mainly just about statistics, I'm not sure how you can really incorporate geometry into it, but I think after seeing that I really saw like actually how you could incorporate it.** I remember there was one problem about gerrymandering and how like they use that to incorporate geometry into it. And

so, I definitely say social justice and math do go together (Interview, 12/17/20, emphasis added).

Prior to learning about such connections in her university coursework, Iris admitted that she did not always think about the connections between mathematics content and antiracism or social justice. Exploring tangible examples of STEM content connections to ARSJ teaching practices on the university campus perhaps began to bridge a divide between not only STEM content and ARSJ teaching, but also between theory and practice. Not only were student teachers learning about ARSJ mathematics theory on campus, but they were observing these ideas come to life in Matthew's classroom, thus further potentiating the use of such practices in their own classrooms. Viewing theory as connected across contexts, as well as viewing theory in action, as opposed to theory devoid of practice, appeared to create stronger connections for student teachers in developing conceptions of ARSJ mathematics teaching practices.

As more courses are offered on Fairfield's campus for both student teachers and residents over time, it is important to consider not only the physical location of such courses, but also the content presented to teacher learners. Throughout interviews, Iris and Aaron mentioned their desire for more coursework focused on their experiences at Fairfield and more connections to antiracist content specifically. Because Aaron and Iris's methods and field instruction seminars were held outside of Fairfield on the university campus, they learned alongside student teachers who were placed in other contexts. Thus, not all discussions were focused on Fairfield and issues that most directly impact their students. For example, Aaron pointed out that his university coursework focused heavily on "access," but "more explicit antiracist teaching and different ways to make sure you're being anti-racist as a teacher" would have benefitted him as a pre-service teacher (Interview, 4/27/21). Similarly, Iris mentioned that antiracism was talked about

“a lot” in coursework but felt that it was “never really hit head on” (Interview, 12/17/20). This sentiment around implicitly addressing antiracism was also seen in student teachers’ interactions with Matthew. Although both student teachers felt they learned a lot about antiracist teaching from Matthew, they also felt that the subject was never truly explicitly addressed, further highlighting the need for additional scaffolding within TTS model to support such conversations across participants.

Although both Iris and Aaron learned about social justice-specific mathematics content in their methods course, Aaron revealed that he did not feel that he took a lot away from his coursework. Instead, he pointed to Matthew, his attending teacher, as his biggest source for learning to teach in ARSJ ways:

I feel like I didn't really take a lot away from the classes that I had this year. I got a lot out of the [multicultural education] class from last winter in terms of antiracist teaching and its importance and impacts and what can happen if that's not your philosophy for teaching. But this year, **a lot of what I took away was just from watching Matthew or the conversations that we had with Matthew about teaching**, equitable teaching practices or helping students or lifting students up and not bringing them down if they mess up, giving them chances and different ways to teach for justice and equity from Matthew (Interview, 4/27/21, emphasis added).

Aaron’s comments above highlight the significance of the attending teacher-student teacher relationship, and the potential to further connect university and Fairfield contexts. Here, Aaron asserted that most of his learning of ARSJ mathematics teaching practices came from experiences with his attending teacher, rather than with engagement with university coursework.

Extending coursework into participants' first few years of teaching as a resident has the potential to address more ARSJ-specific pedagogical moves. As an example, residents Stella and Kendall participated in a summer course designed to develop disciplinary literacy tools towards socially just teaching. The course included residents, as well as other teachers at the school, which, according to Kendall, worked to build community amongst those present. Stella described the opportunity to think about "literacy and social justice" throughout this course as "huge" in terms of her development as a teacher (Interview, 11/2/20).

Student Teachers' Perceptions of ARSJ Mathematics Teaching Practices

Student teachers Iris and Aaron both viewed connections between mathematics concept and skill learning and ARSJ teaching practice as important, though challenging to integrate into perceptions of, or approaches to, practice at times. Based on interview data, Iris and Aaron's perceptions of mathematics content and ARSJ teaching practices were integrated, but still contained blind spots. Both student teachers readily made connections between mathematics content and ARSJ teaching practice, though blind spots occurred when considering how to move such theory into practice. Although, I hypothesize that such a stance might be developmentally appropriate for student teachers with nascent pedagogical knowledge and skills. As pedagogical experience increases, blind spots may be filled or uncovered in more nuanced ways, though the scope of this dissertation does not allow for such type of analysis.

Throughout her interviews, Iris recognized the importance of addressing ARSJ themes and practices in her mathematics classroom, yet there was still a sense of separateness. In the interview excerpt below, Iris explained that it is critical for teachers to recognize students' racial identities and take the time to discuss current social justice issues. However, she also stated that doing so requires a 'time out' of sorts from mathematics teaching:

people can claim that they're not racist and say, I don't see color, but I think in this day and age, it's about seeing color and seeing that you do have White students, you do have Black students, you do have Brown students, you know, and being able to recognize the struggles of marginalized groups. And especially as a teacher when situations, like for example when it came to George Floyd and things like that, actually recognizing it in the classroom and addressing it with your students and being able to have those conversations with them **means taking time out of the lesson to talk about it**" (Interview, 12/17/20, emphasis added).

In the example of George Floyd, which Iris highlighted above, it is perhaps appropriate to take time out of the lesson and address such issues with students. However, at the end of her student teaching, Iris continued to emphasize a separation between mathematics concept and skill learning and ARSJ teaching practices in her interviews. Specifically, Iris did not view standardized mathematics test preparation as part and parcel to ARSJ teaching. Rather, she took this idea one step further and emphasized that students' mental and emotional well-being is sometimes more important than content, stating: "our students are people, and sometimes our priority doesn't have to be the content, but rather their mental health and just their well-being" (Interview, 4/20/21). Additionally, she mentioned that a hyperfocus on test preparation, is sometimes a downfall of a lot of schools, especially with predominantly Black and Brown students that come from lower income backgrounds. We can show them that there are other opportunities besides just taking tests and getting into college (Interview, 4/20/21).

In highlighting Iris's words, I do not intend to imply that students' mental and emotional well-being is not important. Rather, I wish to emphasize the idea that both socio-emotional supports

and disciplinary learning can be equally important and finding that balance is critical to transformative STEM education. Attending to students' well-being means you are doing so in myriad ways that include both socio-emotional learning and the development of disciplinary concepts and practices. Additionally, it is important to consider how the unique virtual context of the online school year could have played a role in Iris's views on prioritizing students' mental health and well-being. As mentioned in previous chapters, students were facing immense trauma outside of school during the 2020-2021 academic year. Thus, perhaps there were instances where students' mental and emotional health took priority over the learning of mathematics concepts and skills. Nonetheless, when engaging students in learning in the mathematics classroom, student teachers and attendings should attend to both mathematics concepts and skills *and* ARSJ teaching practices.

Relatedly, Aaron perceived mathematics instruction and social justice as perhaps more intertwined, stating that he was "attracted to social justice-based learning" because he wanted to think about "how we can use concepts from math class and apply those to real world situations that potentially help others, or be able to understand math in the context of real-world issues in general" (Interview, 12/10/20). One potential blind spot within Aaron's perceptions of STEM content connections to ARSJ teaching practices is also the notion that preparation for standardized testing is somewhat separate from ARSJ teaching. In the excerpt below, Aaron described a conversation he had with Matthew, and how all mathematics learning should be connected to some type of real-world situation, which, according to Aaron, does not necessarily include standardized test preparation:

We had a conversation earlier this week about geometry leading to a conversation about gerrymandering, because **I feel like it's just kind of useless to memorize a**

set of formulas like area of a triangle is one half base times height. And it's like, well, what's the point of learning that if there's nothing we really can do? Which, I know is tricky because you still want to make sure kids are ready for standardized testing because that's kind of how it's set up now, and **you're doing a disservice to students by not teaching them those things, even if they do seem kind of superficial** (Interview, 12/10/20, emphasis added).

In analyzing Aaron's words, I point out how preparing students for gatekeeping exams is a real-world issue, albeit one that deserves major revisions. Aaron does acknowledge that withholding information about test preparation is a disservice to students, which does attend to the underlying foundation of STEM concept and skill learning in the enactment of ARSJ STEM teaching practices. If students are to reimagine a status quo, they must first be able to operate within an existing status quo, which currently includes successful performance on standardized assessments. If Aaron had gone one step further and described how building mathematics concepts and skills, ones that might be useful on a standardized test, supports a movement towards ARSJ teaching and learning, his perceptions of ARSJ mathematics teaching practices would have been further integrated.

Learning from Participants' Perceptions of STEM Content Connections to ARSJ Teaching Practice

In conclusion, I offer thoughts on potential causes within TTS model related to differences in participants' learned ideas of ARSJ STEM teaching. Throughout analysis, I often questioned why it was the case that Kendall faced so many challenges while attempting to integrate elements of ARSJ teaching into her physical science class, while Stella appeared to do so much more seamlessly. It appeared that Stella was able to use her experience and support

from the year prior as a catalyst in improving and carrying out her ARSJ engineering instruction during the 2020-2021 school year. Unlike Kendall, Stella had the opportunity to work closely with a residency support coach to iterate on her practice and learn about elements of ARSJ STEM teaching practice with the benefit of being in-person for much of the 2019-2020 school year. As Stella entered the 2020-2021 school year online, she had the previous year's experience to learn from and ultimately use as a jumping off point for incorporating more social justice topics in her modeling portions of class. Dissimilarly, Kendall began her first year as a teacher of record online with little to no experience with ARSJ science teaching from the year prior. Although Kendall's student teaching experience was in-person, she did not appear to have the opportunity to observe extensive or explicit ARSJ STEM teaching practices on the part of her attending teacher. Kendall's combination of resistance to feedback, blind spots in her perceptions of ARSJ science teaching, and her position as a first-year teacher could begin to explain some of the differences in practice that appeared in the data. Moving forward, it is important to understand participants' place, experience, and perceptions within TTS model so we can best design and carry out supports. Furthermore, cultivating more meaningful relationships amongst intergenerational teams (i.e., student teachers – residents – attending teachers) could have allowed for Kendall, and others, to draw on additional viewpoints and expertise in learning about ARSJ STEM teaching practice.

When considering student teachers Aaron's and Iris's experiences in developing perceptions of ARSJ mathematics teaching practice, it appears that the most significant source of learning was the attending teacher. This has important implications for placement of student teachers and alignment between attending teachers and the school or university philosophy. As seen with Kendall in the previous chapter, she was not placed with an attending teacher who

viewed ARSJ science teaching in the same way as defined throughout this dissertation. Could this have made an impact on how she approached learning about ARSJ science teaching, as well as her stances on learning as a teacher? Although I do not intend to assign causation, it is worth considering how an attending teacher's philosophy and enactments play a role in developing student teachers', and residents', emerging practice. As we continue to build out TTS model, it is important to consider how attending teachers approach practice, how TTS model supports their learning, as well as their commitment to simultaneous student and teacher learning towards ARSJ aims.

Chapter 7 Conclusions and Implications

In writing this dissertation, I set out to explore teacher learning within a case of a unique reform model of educator preparation through the lens of pre-service and beginning teachers' experiences. In doing so, I sought to develop an understanding of the ways in which TTS model supported or constrained STEM teacher learning towards ARSJ aims. As such, an intended outcome of the study was to contribute to research around more effective preparation and support of STEM teachers for transformative learning environments in under-resourced areas. In this chapter, I review my findings presented in chapters 4, 5, and 6 and offer conclusions, implications, and future directions for research. As a reminder, the research questions that guided my study were:

1. What are the opportunities to learn ARSJ STEM teaching practices made available through The Teaching School model?
 - a. How do participants take up such opportunities to learn?
2. How do participants talk about their perceptions of ARSJ STEM teaching, as it relates to their teaching practice and development?
3. How does The Teaching School model support and constrain prospective and novice teacher development around ARSJ STEM teaching practices?

Summary of Findings

Because participants self-selected into TTS, I expected there to be some degree of uniformity across participants' perceptions of ARSJ STEM teaching practices and their commitments to developing their practice towards these aims. And yet, after examining only four

different interns and residents' experiences of learning to teach within the model, I found distinct differences in how participants navigated the model and engaged in and took up opportunities to learn. Participants not only arrived at TTS with varying degrees of commitments to improve on practice and understandings of ARSJ STEM teaching practices, but they also engaged in opportunities to learn ARSJ STEM teaching in different ways. Furthermore, the virtual nature of the school year presented a unique context within which to study participants' learning and perceptions of ARSJ STEM teaching practices. Conducting classes, observing practice, and participating in coaching sessions and other supports became much more isolated and individualized than anticipated in the idealized design of TTS model. These factors contributed to the differences in engagement and uptake of opportunities to learn ARSJ STEM teaching practices, as well as differences in the perceptions of ARSJ STEM teaching practice that I observed across participants.

First, I explored how participants' experiences in learning ARSJ STEM teaching practices were situated within the larger school culture. I found that participants were met with challenges to alignment when it came to a school culture focused on ARSJ STEM teaching practice. Data related to school culture and attending teachers suggested that although school community members were dedicated to ARSJ teaching practices, their perceptions and approaches to practice varied. In chapter 4, I presented Aaron's and Iris's experiences with Matthew in contrast with Kendall's experience with Kira. Although Matthew represented a more-aligned view of ARSJ STEM teaching practices as presented in this dissertation, Kira's practice – as represented by Kendall – appeared somewhat misaligned with Kendall's view of ARSJ STEM teaching practice. This perceived misalignment with her attending teacher presented Kendall with difficult decisions on what to incorporate into her practice as a first-year

teacher seeking to teach in ARSJ ways. For example, Kira's views of Fairfield (as reported by Kendall) as a school for the *best of the best*, and her explanation of a seating chart as *placing the smart kids in the front*, could have shaped Kendall's learning of ARSJ science teaching as she entered her first year of teaching. Furthermore, the virtual schooling context appeared to have impacted the school's efforts to build a cohesive and developing shared vision in relation to ARSJ teaching practice across disciplines.

In addition to varied experiences within the larger school culture, participants' engagement with and uptake of learning opportunities made available through TTS model varied across participants. In the cases of Stella and Kendall, both residents appeared to participate in the same opportunities, yet their engagement within those opportunities and how they enacted instruction as a result were very different. First, Stella continuously emphasized the importance of consistent and constant reflection throughout her interviews, and it became clear that she used opportunities to reflect with attending teachers, attending teacher educators, and Kendall to iterate on her practice. In pre-interview data (11/2/20), Stella also pointed out that she chose to join TTS because she saw great value in having others observe her practice and the act of engaging in reflection with others. As Stella said, "I think learning happens best together, and I think unlearning happens best together" (Interview, 2/16/21). Thus, Stella approached her participation in TTS as working with and learning from others to improve her own practice. In the example shown in Chapter 5, Stella identified an area of need in her curriculum, used coaching sessions to reflect on this need, and then used the design thinking process to devise a plan to improve the presentation format for her engineering students. Even after she implemented the change, Stella continued to reflect on how it could be made even better and more equitable for her students in the future. In instances such as this, Stella displayed a deep sense of

commitment to improve her practice and connect to her agency as teacher. She engaged in a self-reflective process and considered how she could use her position as a teacher to change learning experiences and outcomes for her students towards more ARSJ aims.

By contrast, Kendall approached TTS model differently from Stella, though she still engaged with opportunities to learn ARSJ STEM teaching practices. As a first-year teacher attempting to teach online through numerous traumas imposed by the pandemic, Kendall could have been simply trying her best. At the beginning of the school year, Kendall attempted to act with agency by developing her own curricular materials, though she declined opportunities for curricular support during the previous summer months. When prompted with feedback on how to make these materials richer in disciplinary literacy practices, Kendall interpreted the feedback in ways that might be expected of a first-year teacher who is learning to integrate multiple pedagogical moves, knowledges, and skills at once. In response to feedback, Kendall ultimately asked students to document factual knowledge but did not ask them to synthesize ideas across multiple readings. However, Kendall's engagement with learning opportunities to reflect on and improve her practice were often met with resistance and defensiveness, which cannot be wholly attributed to her position as a first-year teacher. I found that although Kendall significantly reduced the pace of her course, she may have been doing so to reach all students, as well as perhaps orient herself to a new curriculum and a new experience as a teacher. As Kendall pointed out, she wanted to feel more expert, yet she did not "quite always know how" (Interview, 6/24/21), while at the same time rejecting the supports she was provided. In this way, Kendall appeared to exude a commitment to ARSJ STEM teaching practices, yet she did not fully portray a commitment to improvement on her own practice, or knowledge of how to improve.

Although my findings did not shed light on student teachers' practical enactment, I did find engagement in opportunities to learn to be quite consistent across both Iris and Aaron. Both student teachers praised their attending teacher, Matthew, as one of their most important sources for learning to teach. The time spent before class started was largely used to talk through the plans for the day and about issues of ARSJ mathematics teaching practices. This structure stayed in place throughout the year, yet the focus of conversation shifted as student teachers took on more responsibility, instead focusing on what Iris and Aaron were planning to teach. Through these **morning** meetings, Matthew and student teachers cultivated a critically supportive community of practice that was focused on both student learning and teacher learning. I routinely observed productive critique and questioning in both Matthew's feedback to student teachers, as well as student teachers' questions for Matthew. As noted in chapters 4 and 5, Matthew used chat features in Microsoft Teams to provide in-the-moment feedback for student teachers. Aaron also reflected on how he felt comfortable asking Matthew about an area of teaching practice that he felt conflicted with the equitable grading practices Matthew had discussed with them throughout the year. This bi-directional relationship allowed for Iris and Aaron to connect to their agency as student teachers and improve their interactions with students in real-time, further emphasizing goals of both student and teacher learning towards ARSJ STEM teaching aims.

In addition to exploring participants' engagement with and uptake of learning opportunities, I also found variations in perceptions of connections between ARSJ teaching practice and disciplinary STEM concept and skill learning. Across the data, I found that all participants wanted to draw meaningful and intentional connections between ARSJ teaching practices and their respective STEM concepts and skills. However, participants displayed tensions when it came to enacting such connections in their curricular development and

implementation with students. Both Aaron and Iris felt that there were many connections between mathematics and social justice, as evidenced by their experience in a university methods course and observations of Matthew's teaching. Yet, they both displayed tensions around incorporating mathematics content and real-world connections in their own teaching. For example, both student teachers identified standardized testing in mathematics as a reality of teaching, but something as separated from ARSJ teaching practices. Such findings provide insight into how student teachers perceived the relationship between access and equity. It would appear as though both student teachers achieved high academic scores themselves, as they were admitted into a competitive large research university upon graduation from high school, where they simultaneously took courses in both the school of education and mathematics department. Thus, tensions such as these should be explored – did student teachers feel conflicted because they knew what they had to do to succeed and struggled to ensure that their students could do the same while engaging in ARSJ STEM teaching practices? It could have been the case that student teachers felt a need to teach students how to work algorithms quickly, which could be situated as largely separate from a real-world or relevant context. They could have also felt that focusing on applications for mathematics in society would not help students learn algebra or geometry foundations. How do we support pre-service and beginning in-service STEM teachers to find a balance between a focus on foundational skills and their application to real-world connections?

Kendall displayed similar tensions in her perceptions of ARSJ science teaching practice. Although she recognized the importance of representation in her curriculum, and adapted her curriculum to reflect students' interests, identities, and lived experiences in a few instances, she also felt that doing so took time away from the teaching of science content. Furthermore, Kendall noted that adapting curricular materials towards more ARSJ aims required a lot of energy and

effort on her part as the teacher, as such materials were not readily available. Thus, how do we help TTS participants access and develop these materials in ways that allow them to do meaningful ARSJ work, while also considering the realities of district-mandated curricula? Perhaps some answers might come from studying how Stella navigated these tensions.

Stella appeared to engage in learning opportunities and incorporate ARSJ engineering teaching practices most seamlessly into her teaching, as she viewed ARSJ as a lens through which to approach all pedagogical decisions and interactions with youth: “it has to be a part of everything you do” (Interview, 6/29/21). Throughout the 2020-2021 virtual school year, Stella found many ways to connect ARSJ teaching practices with disciplinary engineering concepts and skills, although, she also felt there was more she could have done. Stella mentioned that she was proud of the ways she was incorporating ARSJ themes into her modeling with students and felt that this was more successful than the year prior, but “action is questionable” (Journal Entry, 12/14/20) when it came to project implementation with youth. Thus, it appeared as though Stella’s views of ARSJ engineering teaching became somewhat more narrowed when it came to practice. Given Stella’s overall stance, it is important to consider how TTS model structures opportunities for participants to learn about and develop views of ARSJ STEM teaching practices that touch almost every aspect of teaching from mindset to practice. How do we support TTS participants in becoming a teacher who approaches all aspects of practice through an ARSJ lens, and not simply when the content presented to students has direct ties to an issue of social justice?

General Takeaways

When taken as a whole, these findings suggest that participants learned a great deal about ARSJ STEM teaching practices within TTS model, yet there are many lessons to take away for

programmatic improvement. First, differences in participants' experiences and stances on teacher learning suggest that designing supports does not appear to be a one-size-fits-all model. Although consistencies across the model are necessary for logistical and potential replication purposes, especially as the school continues to grow, it is important to bear in mind the differences in both experience and mindset that interns, student teachers, and residents bring with them to TTS. Relatedly, differences in student teaching experiences across Aaron, Iris, and Kendall suggest that attending teachers' differences in approaches to ARSJ STEM teaching practice and stances on learning are equally critical to building a stable model that can allow for the construction of a shared vision while also making room for differences in viewpoints. The model design also needs to be thoughtful about how perspectives shape practice and build structures, commitments, and practices that help teachers learn about and enact ARSJ STEM teaching practices.

Although Kendall ultimately chose to leave TTS midway into her second year of residency, her experience was an important factor in understanding how current TTS structures worked to both support and constrain teacher development. Because the year of student teaching is so foundational, Kendall's experience with Kira could have been indicative of the ways in which Kendall approached learning to teach through TTS supports in her first year as a resident. Although Kendall made mention of the ways in which she wished to distance herself from Kira's practice, data suggested that her overall resistance to observation, feedback, and support could have been reinforced by her student teaching experiences. Similarly, Iris and Aaron mentioned their concern around only viewing Matthew's teaching, even though they tended to agree with his teaching philosophy. Such experiences suggest that TTS model has the potential to provide participants with a singular view of teaching and learning, even if such views are aligned with

ARSJ STEM teaching practices. However, it is important to note that the year of data collection only offered student teachers one mathematics attending teacher and limited opportunity to observe practice outside of Matthew's classroom in the online schooling environment. As such, as the school grows, TTS model could consider more varied learning experiences for participants across the school with the participation of additional attending teachers, or other staff members in the Fairfield community.

In addition to differences across participants' student teaching experiences, it appeared that although participants engaged in opportunities to learn ARSJ STEM teaching practice with attending teachers and attending teacher educators, these interactions did not extend beyond these relatively small communities of practice to the rest of the school. Although residents participated in bi-weekly staff meetings and evaluation cycles with administrators throughout the year, such settings encompassed the extent, and perhaps possibilities, of staff interactions throughout the virtual school year. Thus, it became difficult to cultivate an aligned online community across goals of student and teacher learning through ARSJ teaching practices. This meant that student teachers and residents largely learned about ARSJ STEM teaching practice from their virtual interactions with immediate TTS support contacts. Although this is not a limitation in and of itself, extension of ARSJ conversations with the wider Fairfield community could have led to additional supports for participants.

Successes and Challenges in Engagement in and Uptake of Opportunities to Learn ARSJ STEM Teaching Practices

Across participants' data, there were multiple and varied instances of engagement in and uptake of opportunities to learn ARSJ STEM teaching practices. In this section, I summarize what I found in relation to each participant's successes and challenges in learning about ARSJ

STEM teaching practice, how this potentially manifested in the practice I was able to observe, and what this means for implications for the study. Below, I present annotated frameworks of ARSJ STEM teaching practices that serve to describe the types of practices participants were able to learn about, and attempt to enact, as part of their participation in TTS.

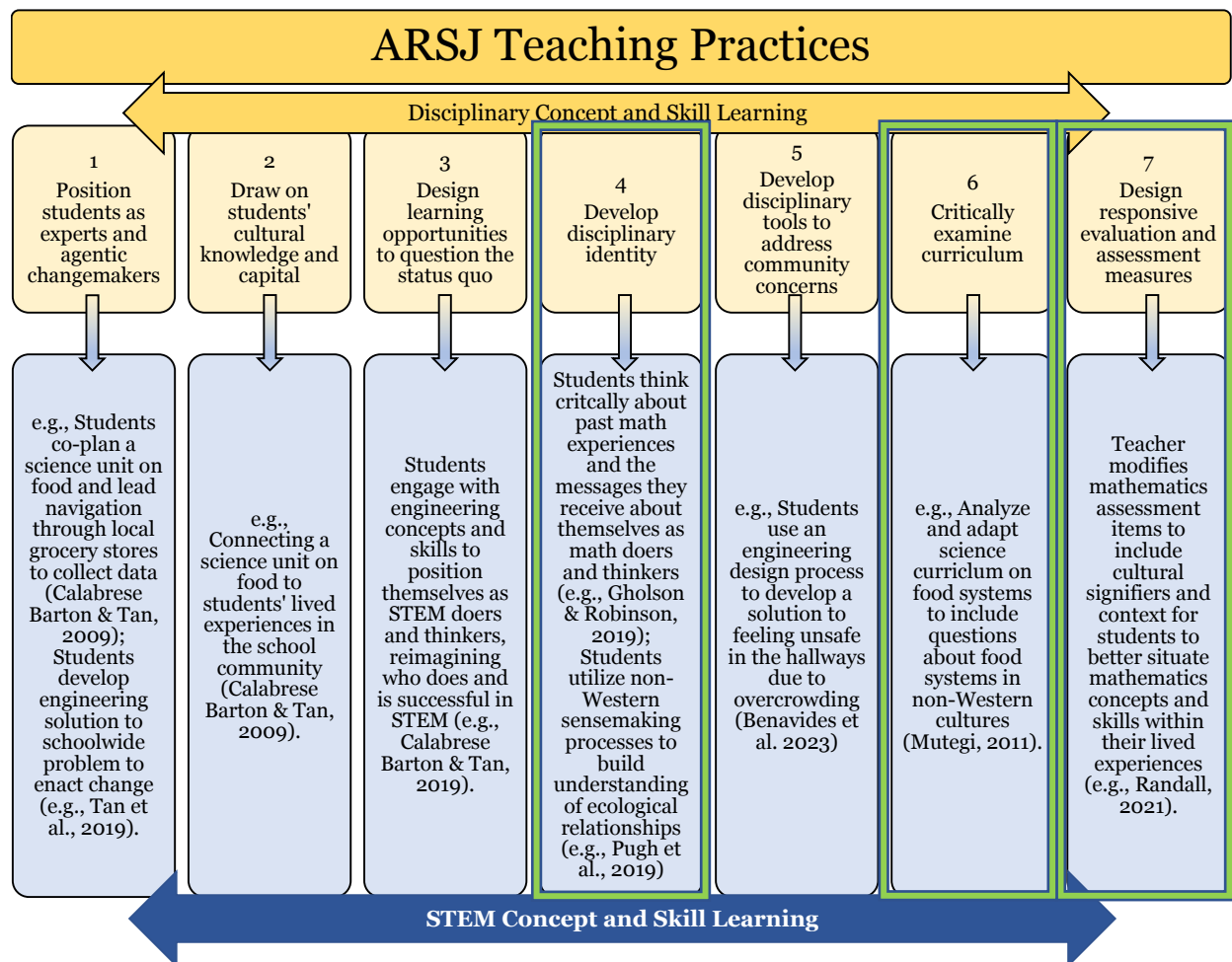


Figure 7-1 Aaron's and Iris's engagement in and uptake of opportunities to learn ARSJ STEM teaching practices

Both Aaron and Iris were able to learn about ARSJ STEM teaching through interactions with their attending teacher and university coursework. As evidenced by interview data throughout the 2020-2021 virtual school year, I identified three main areas of focus that came up across the two student teachers' experiences. First, both Aaron and Iris spoke about their

opportunities to learn about and observe Matthew's integration of non-White mathematicians into curricular materials, which required a critical examination of the curricula and supported students in building disciplinary identity by widening possibilities to see themselves as math doers and thinkers. Additionally, Iris spoke about her own opportunity to integrate non-White and non-male figures into the curricular materials she presented to students, thus demonstrating both engagement in and uptake of opportunities to learn ARSJ mathematics teaching.

Additionally, Aaron and Iris spoke about their opportunities to critically examine and adapt curricular materials towards more ARSJ aims in their university coursework. Learning about such practice from both contexts could have further supported student teachers' engagement in and eventual uptake of ARSJ STEM teaching practices. Furthermore, Matthew's focus on equitable grading practices allowed student teachers to learn about responsive evaluation and assessment measures, particularly as it related to an online school year.

Although Aaron and Iris learned about the ARSJ STEM teaching practices outlined above, there are still several practices I did not observe as part of their learning to teach within TTS. There could be several explanations for this. First, virtual constraints of the online school year precluded me from observing their (and Matthew's) practice in meaningful ways. Thus, it could have been the case that more practices were highlighted and enacted, but I was not privy to such practice as part of my data collection. Second, Aaron and Iris could have highlighted the practices outlined above as part of their interviews because they were the most salient to their experiences as student teachers. Although Matthew could have been engaging in full integration of all seven practices, Aaron's and Iris's novice perspectives could have narrowed in on areas that were brought up most by Matthew (responsive evaluation) and coursework (critically examining curriculum). Last, Aaron and Iris could have simply not had the capacity to learn

about additional practices as part of their pre-service training experience. Such an insight could imply that certain aspects of ARSJ STEM teaching practice are introduced at different points in time throughout one’s journey in learning to teach. Identifying and learning about all seven practices at once could prove to be overwhelming and perhaps counterproductive for pre-service teachers. Designing structures to scaffold learning about ARSJ STEM teaching practices, particularly for pre-service teachers, is discussed later in this chapter.

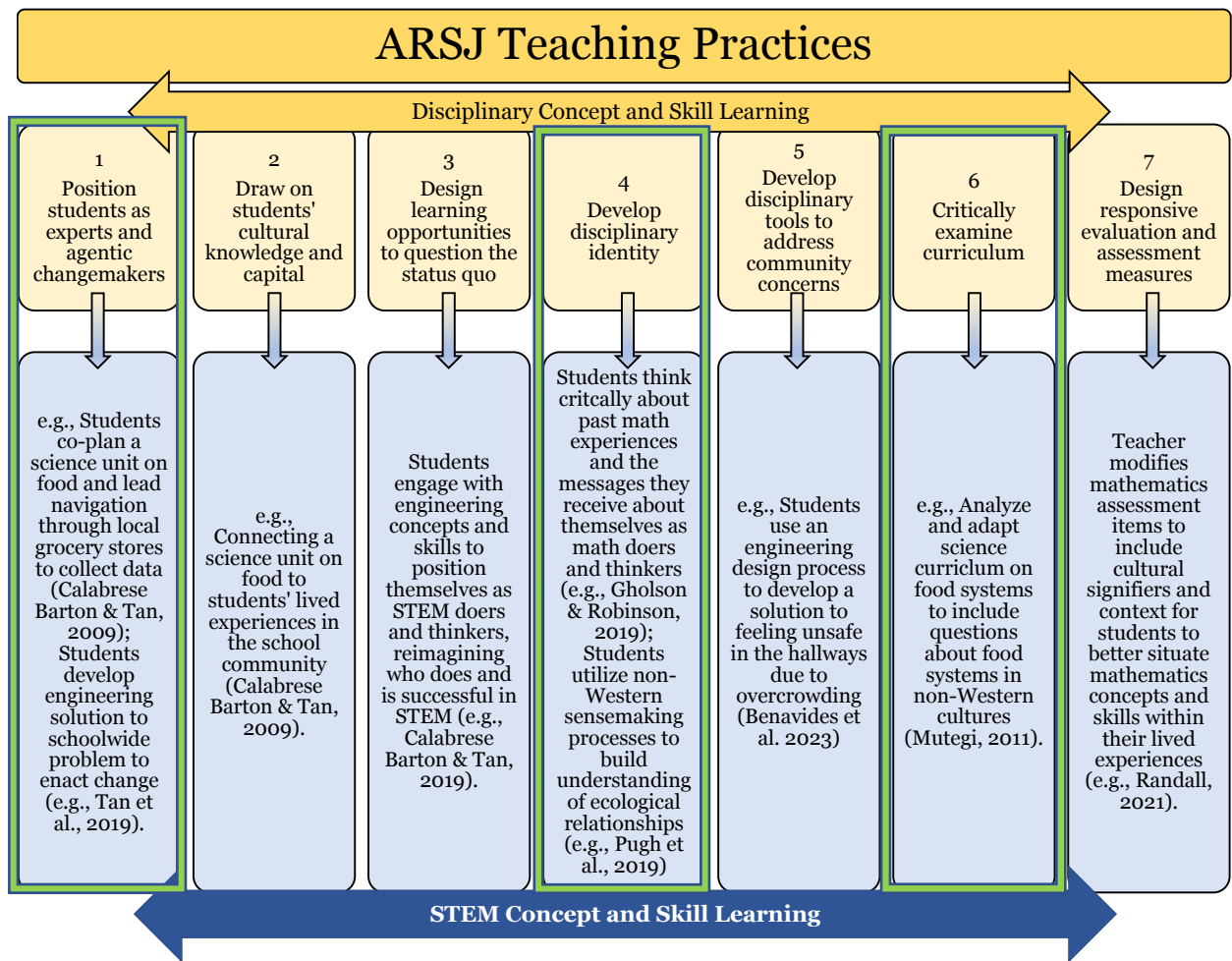


Figure 7-2 Kendall’s engagement in and uptake of opportunities to learn ARSJ STEM teaching practices

Although data suggests Kendall faced many challenges in learning about and enacting ARSJ STEM teaching practices, I did observe success in a few areas. As explored throughout

chapter 6, Kendall found an area of her curriculum to adapt and include representation of a Black woman using a Van de Graaff machine, connecting students' expertise on hair type and texture to scientific concepts of weight, mass, and electric force. However, instances such as this did not appear consistently throughout her data, suggesting it was difficult for Kendall to not only learn about but enact elements of ARSJ STEM teaching practice throughout her first year as a teacher of record. It is important to note that Kendall did bring up desires to both widen representation in efforts to allow students to see themselves as science doers and thinkers, and critically examine her curriculum. However, such opportunities to learn about these ARSJ STEM teaching practices and others were often met with defensiveness and hesitancy to engage. Thus, although Kendall talked about her conceptions of elements of ARSJ STEM teaching practices, few of these opportunities made their way into practice. This could be due to a variety of factors. First, Kendall's commitment to ARSJ STEM teaching practices did not appear to be coupled with a commitment to improve upon her practice. As I explore throughout this chapter, successful learning of ARSJ STEM teaching practice appears to be linked to both a commitment to ARSJ STEM teaching practices *and* a commitment to improving on one's own practice. Without such a commitment to improve, it appears that Kendall was unable to fully engage in learning opportunities and take up such opportunities in her practice. Second, it could also be the case that Kendall was committed to improving on her practice, but she may have faced challenges when it came to reflexivity and identifying areas of personal growth. Third, this also could have been coupled with a need to develop a knowledge of *how* to improve on practice. As a first-year teacher, learning to incorporate feedback could have proved challenging. Such an insight suggests that perhaps more scaffolding or modeling of how to implement feedback and improve on practice towards ARSJ aims is necessary. These supports could take the shape of case

conferences with residents, co-planning, and co-teaching opportunities. Last, Kendall may have had fewer opportunities to learn about and enact ARSJ STEM teaching practices given the unique online nature of the school year. Where a traditional in-person setting could have offered additional intergenerational learning opportunities, the online school year proved isolating and challenging to engage in an intentional and supportive community of practice, which could have further benefitted the learning of all participants.

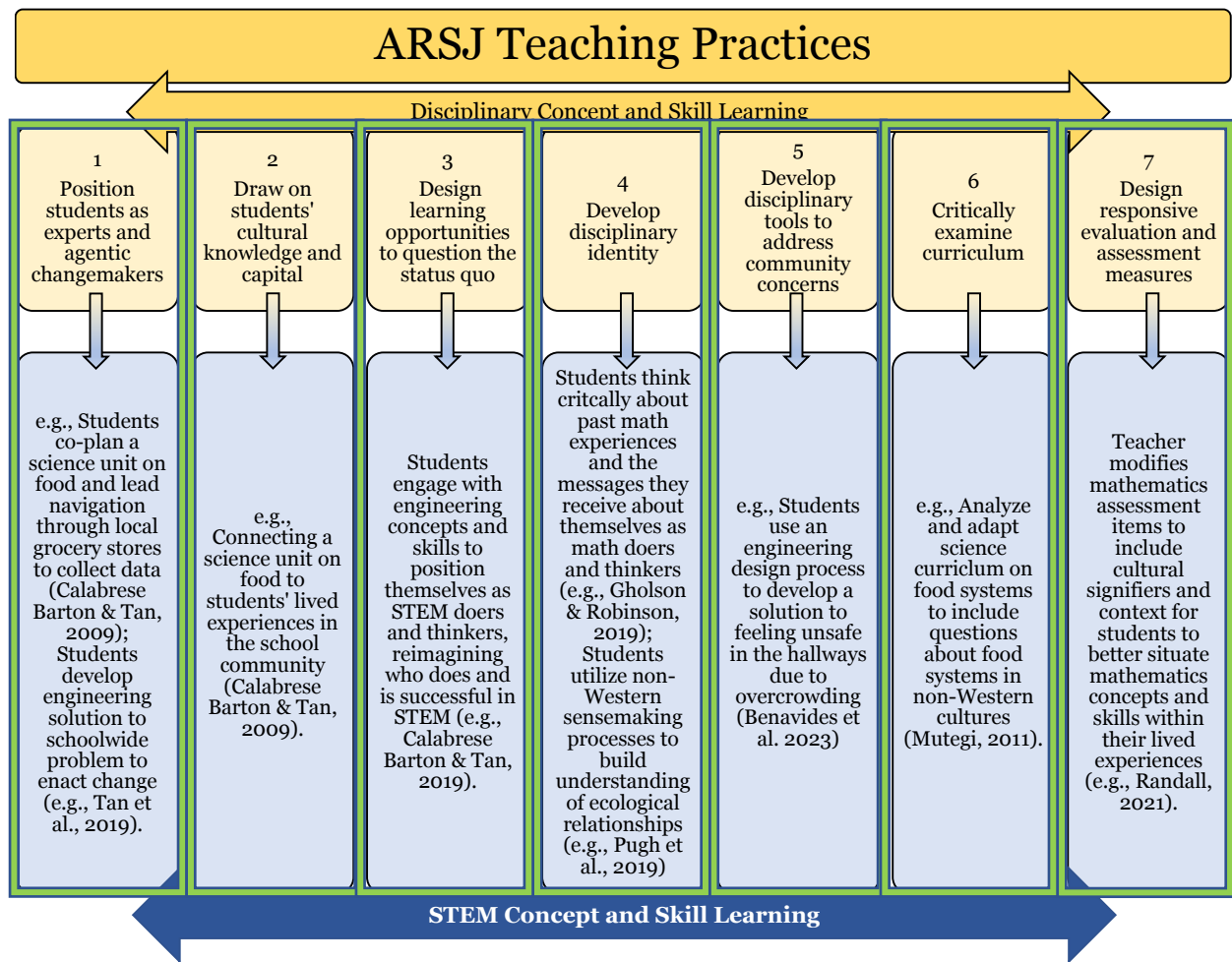


Figure 7-3 Stella’s engagement in and uptake of opportunities to learn ARSJ STEM teaching practices

As previously stated, Stella appeared to engage in and take up opportunities to learn ARSJ STEM teaching practices most effectively. Figure 7-1 (above) depicts ARSJ STEM

teaching practices as connected to areas of her learning and practice that I observed, as outlined in green. Through Stella's design thinking curriculum (see chapter 5), she designed multiple and iterative opportunities for students to develop engineering tools to address community concerns, which allowed students to experience and see themselves as successful STEM doers and thinkers, develop an identity as an engineer and designer, and positioned students as experts and agentic changemakers, as well as draw on students' cultural knowledge and capital. When Stella was not sure about how her assessment practices attended to students' needs, she worked with attending teacher educators to critically examine the existing curriculum and design a more responsive assessment measure for students. Stella's integration of all seven ARSJ STEM teaching practices into her mindset and practice demonstrate successful engagement in and uptake of learning opportunities within TTS model. Not only was Stella committed to viewing all aspects of her practice through an ARSJ lens, but she was also committed to improving on her practice and leaning into TTS supports to do so. Such engagement demonstrated Stella's commitment to her teaching, as well as her reflexivity in understanding where she could improve and subsequently acting on such goals.

Stella's success in learning to teach engineering in ARSJ ways suggests two implications for TTS model. First, it suggests that participants need to commit to both learning about ARSJ STEM teaching *and* commit to actionable improvement on their practice. Committing to improvement requires certain levels of reflexivity, reflectiveness, and openness to feedback. It is one thing for a participant to commit to improving their practice, but it is another to engage in such improvement and recognize areas of strength, improvement, and support from attendings and peers. Not only was Stella offered opportunities to learn, but she leaned into such opportunities and initiated feedback on her practice. Secondly, Stella's success relative to other

participants suggests an opportunity for intergenerational learning by way of near-peer observations. TTS residents and student teachers could observe each other's practice and consider where they found instances of ARSJ STEM teaching practices. These observations could be discussed and analyzed in seminar spaces, allowing both the observer and the one being observed to talk through their reasoning, as well as where the class period(s) being observed fit within the larger curricular picture. Furthermore, in the case of Stella, she could talk through where she initiated feedback and how she intended to use such feedback in improvement on her practice. Such modeling could aid in intergenerational learning and work towards the normalization of feedback within the model.

Mindset and Heartset: Participants Approaches to Learning ARSJ STEM Teaching Practices

Data across all participants suggests a foundational mindset and heartset towards ARSJ STEM teaching practices. Here, I use the terms mindset and heartset to encompass both a frame of mind and a frame of heart when committing to teaching in ARSJ ways, which I argue are both critical as a baseline to developing successful and transformative ARSJ STEM educational experiences for youth. All participants, whether successful in practical enactment or not, were committed to teaching from a place of ARSJ STEM teaching practices and exuded this baseline mindset and heartset – no participant was actively anti-ARSJ STEM teaching. However, such a baseline is not enough to successfully enact ARSJ STEM teaching practices. Although I suggest that this baseline is critical for such development, mindset and heartset needs to be coupled with a strong commitment towards improvement on practice. Participants who were more successful in developing and enacting elements of ARSJ STEM teaching practices exhibited both a commitment towards ARSJ STEM teaching *and* a commitment to consistently improve on

practice. For example, when comparing the cases of Stella and Kendall, both residents appeared to exude both a mindset and heartset towards ARSJ STEM teaching practice – they both applied for TTS and spoke at length about their commitments to ARSJ STEM teaching in both pre-employment interviews and dissertation interview data. However, when it came to engagement in learning opportunities, data suggested that Stella exuded a far greater commitment to improving her practice than Kendall, which could have shaped the ways in which both residents engaged with and took up opportunities to learn ARSJ STEM teaching practices. Similarly, early data analysis on Iris’s first years as a TTS resident suggest that she is not engaging in feedback and opportunities to learn that would exude a strong commitment to continuous improvement on practice. Thus, baseline commitments to ARSJ STEM teaching must be combined with a strong desire for continuous improvement on practice. Put simply, learning to teach is hard and developing ARSJ STEM teaching practices is not expected to be done without intentional and ongoing support. The desire to accept and utilize support is imperative for a successful TTS model. However, it could also be the case that participants are committed to improving their practice, yet they do not possess the pedagogical knowledge to move theory into practice. As Kendall pointed out in her end-of-year interview, she sought to improve her practice, but did not always quite know how. Such takeaways suggest the need for additional scaffolding of supports and perhaps a stronger screening process designed to attend to participants’ commitments to improvement on practice in addition to a baseline mindset and heartset around ARSJ STEM teaching practice.

Divides Between ARSJ Teaching Practices and STEM Disciplinary Concepts and Skills

Although TTS model is designed to support pre-service and beginning in-service teachers to develop ARSJ STEM teaching practices, participants struggled to find connections between

ARSJ teaching practices and disciplinary STEM concepts and skill learning in practice. As mathematics student teachers Iris and Aaron pointed out, although they encountered many examples of ARSJ mathematics teaching in both university coursework and conversations with Matthew, their attending teacher, both student teachers faced challenges when finding connections in practice. Aaron cited the virtual school year as a limitation to enacting mathematics teaching connected to the real world and students' lived experiences. Additionally, both Aaron and Iris noted standardized testing as something they viewed as separate from ARSJ STEM teaching, although such measures require a deep understanding of disciplinary mathematics concepts and skills, which have the potential for students to develop through engagement with ARSJ teaching practices more strongly. Even Stella, who enacted ARSJ STEM teaching practices most consistently, exuded blind spots when it came to connecting her engineering curriculum to elements of ARSJ STEM teaching practices. For example, as shown in chapter 6, Stella noted that she viewed her enactment of such practices as questionable because her day-to-day teaching was not connected to issues of social justice. However, students were deeply engaged in other aspects of ARSJ STEM teaching practice, including *developing engineering tools and skills to address issues of community concern*. Such a perceived divide between STEM concept and skill learning and ARSJ teaching practices is common, particularly as STEM is commonly viewed as objective and acultural. Thus, how might TTS model support participants in identifying such connections? How might we scaffold opportunities for participants to identify and create stronger connections between their respective STEM disciplinary concepts and skills and elements of ARSJ teaching practice?

Implications

Throughout this dissertation, I set out to learn more about how TTS model supports and constrains new teacher learning of ARSJ STEM teaching practices. Based on my findings, I now present several implications for the program and the broader research community.

Reimagining within TTS Model

Taking the above takeaways into consideration, I use this space to reimagine what TTS model might look like given the set of challenges participants faced in developing ARSJ STEM teaching practices. I divide this section into two areas: idealized visions of TTS supports for 1) pre-service teachers and residents and 2) attending teachers.

Reimagining TTS Pre-Service and Resident Teachers' Opportunities to Learn

Participants' TTS experiences as pre-service teachers have the potential to set the tone for future interactions within intergenerational teams, as well as commitments to continuous improvement on practice. Because TTS model extends pedagogical supports into the first three years as a teacher of record, I reimagine what opportunities to learn might look like that begin in the pre-service stage and extend into the residency stage. Based on my findings throughout this dissertation I would reimagine TTS supports for pre-service and resident teachers' opportunities to learn ARSJ STEM teaching practices in the following ways:

1. Design opportunities for pre-service and beginning in-service STEM teachers to interrogate their identity, power, and privilege, as well as their mindset around STEM as an objective or acultural enterprise.

Within pre-service and beginning in-service learning opportunities, seminar spaces could be dedicated to investigating and developing interns' and student teachers' mindset and heartset when it comes to developing ARSJ STEM teaching practices. One such opportunity could be

autobiographical assignments aimed at developing new perspectives of pre-service teachers' life experiences, relationship to the culture of power, and mindset around STEM as objective and acultural. I envision such assignments to be completed and returned to throughout the pre-service training experience at TTS, as well as revisited during the first years as a teacher of record if student teachers seek to pursue a teaching residency at Fairfield. Revisiting such an assignment could generate new insights into TTS participants' mindset and heartset related to ARSJ STEM teaching practices. Prompts might include:

1. Describe your home culture when you were growing up.
 - a. What language did you speak?
 - b. How did your parents/guardians approach conflict in the household?
 - c. How did your parents/guardians communicate with you when they wanted you to do something or complete a task?
2. Describe your school culture.
 - a. What languages were spoken?
 - b. What role did socioeconomic status play in your interactions with teachers and peers?
 - c. How were decisions made in the classroom?
 - d. How did teachers, staff, and administrators communicate policies, norms, and procedures both inside and outside of the classroom?
 - e. What connections did you experience between your learning experiences and your home culture?
 - f. What disconnects did you experience between your learning experiences and your home culture?

3. Describe your STEM schooling experiences.
 - a. How were STEM learning opportunities framed in your school?
 - b. What opportunities did you have to learn STEM concepts and skills?
 - c. What messages did you receive about who does and is successful in STEM?
 - d. How did your STEM learning experiences translate to noticeable changes made in your school and surrounding community?
 - e. How did your STEM learning experiences influence your career goals and decisions?
 - f. What connections did you experience between your STEM learning experiences and your home culture?
 - g. What disconnects did you experience between your STEM learning experiences and your home culture?

Such questions could then be coupled with opportunities to consider how STEM concept and skill learning is part and parcel to developing ARSJ teaching practices. Furthermore, learning opportunities could consider how such perceptions and experiences translate to pre-service and beginning in-service teachers' needs for scaffolding or additional support when it comes to developing ARSJ STEM teaching practices.

2. Develop ARSJ STEM teaching practices lesson/unit plan template and observation protocol.

In addition to providing opportunities for examining relationships to power, privilege, and stances on STEM teaching and learning, data suggests the need for systematic engagement around observations of ARSJ STEM teaching practices in practice across the school community. One such avenue could be the development and use of an ARSJ STEM planning template and

observation protocol. Designing a planning tool and observation protocol could support student teachers and residents in identifying ARSJ STEM teaching practices in their observations of their peers and attending teachers, as well as provide supports for designing and enacting ARSJ STEM teaching and learning opportunities for youth. I imagine the planning tool and observation protocol to include a copy of the ARSJ STEM teaching practices framework to serve as reference for its users. The planning tool might ask participants to identify targeted elements of ARSJ STEM teaching practices and then consider how their activity, lesson, or unit fits within these goals. The template might also include a set of reflective questions that prompts participants to consider how their activity, lesson, or unit attends to STEM concept and skill learning, as well as identify personal areas of improvement on practice. Such reflective questions could be used as fodder for debriefs and co-planning meetings with attending teachers and attending teacher educators, as well as identify targeted areas for feedback. Further, such questions could scaffold the development of a mindset around continuous improvement on practice. Additionally, the observation protocol would allow for student teachers and residents to identify elements of ARSJ STEM teaching in practice, as well as consider how their near-peers or attending teacher might improve upon practice. This is not to say that the observation protocol would be used as an assessment tool amongst intergenerational teams. Rather, I view the observation protocol as a scaffolding mechanism for TTS participants to observe elements of ARSJ STEM teaching in practice, consider how adoption or adaptation might improve their own practice, and engage in meaningful conversations about developing ARSJ STEM teaching practice within intergenerational teams. The observation protocol could be broken down into distinct practices for pre-service teachers at the beginning of their training and TTS experience,

and then work up to the interconnected nature of the practices and the nuances of how they might manifest in their own and others' teaching.

3. Critically examine district-mandated STEM curricula and provide scaffolded opportunities to adapt and generate new materials for students.

Findings related to perceived divides between STEM concept and skill learning and ARSJ teaching practices shed light on the struggles educators face when attempting to adapt or create more relevant and transformative curricular materials for youth. In Kendall's efforts to adapt her curriculum, she stated tradeoffs between finding relevant materials and preparing for her lessons. As a first-year teacher facing many challenges in learning to teach, Kendall found few opportunities to implement ARSJ-focused science lessons, partly due to the lack of connections in the existing curricula she was working with. Similarly, Aaron and Iris found few connections between ARSJ teaching practices and mathematics concept and skill learning within the mathematics content they were tasked with observing and teaching. In reimagining such supports for student teachers and residents, TTS model could provide intentional opportunities to examine existing curricular materials and practice adapting small portions of lessons or units to incorporate more elements of ARSJ STEM teaching practices. Within seminar spaces, we could examine district-mandated curricula that student teachers and residents interact with in their responsibilities with attending teachers and students. Student teachers and residents could then learn how to examine curricula in a low-stakes environment (i.e., outside of direct interaction or enactment with students), perhaps making use of the ARSJ STEM teaching practices lesson plan template and observation protocol described earlier. Such an opportunity to learn could become more complex, and perhaps more critical, as student teachers increase instructional responsibility and transition into residents who take on the roles and responsibilities of a teacher of record.

Findings also suggest that there is a need for readily available and accessible ARSJ STEM curricular materials to support teachers in carrying out such efforts. Given the challenges new teachers face, the burden should not be solely on educators to adapt and create materials. Such information should be readily accessible, available, and integrated into standard curricular materials across all subjects. Some resources do exist, though they are not explicitly tied to full units of instruction (e.g., The Underrepresentation Curriculum Project, 2022; STEM Teaching Tools, 2022), or they pay closer attention to the social sciences than STEM fields (e.g., zinneducationproject.org). Although training and supporting teachers to adapt materials is one way to address this gap, it does not arrive at the root of the problem. Curriculum designers and publishers should view their materials through a critical lens, as well as consider from whose vantage point do these materials project. One such framework through which to view curricular development is Picower's (2012) *Six Elements of Social Justice Curriculum Design*. However, this framework focuses on elementary classrooms and does not pay specific attention to STEM disciplinary concept and skill learning. Thus, more work needs to be done in terms of designing STEM-specific ARSJ curricular materials to support beginning teachers.

4. Engage in practice teaches with intergenerational teams.

Providing opportunities for student teachers and residents to engage in practice teaches could provide participants with opportunities to intentionally practice elements of their activities, lessons, or units before implementing with students. Ahead of practice teaches, participants could identify an area of their practice they would like to improve on, as well as elements of ARSJ STEM teaching practices they see as applicable or would like support in integrating further. Such an activity would not only benefit student learning, as students would interact with improved instructional materials, but it would also benefit teacher learning and work to

normalize feedback and improvement on practice within TTS. Normalizing feedback as a part of teacher learning in this way could work to strengthen both commitments to ARSJ STEM teaching practices and knowledge of how to improve upon practice.

5. Create goal setting documents for professional development and learning to enact ARSJ STEM teaching practices.

In addition to engaging in practice teach opportunities, student teachers and residents could also create goal setting documents specific to professional development and learning about ARSJ STEM teaching practices. Although residents set goals for themselves throughout the year, these goals were not always specific to elements of ARSJ STEM teaching practices. Allowing participants to identify specific areas of improvement and growth could work to further tailor TTS support structures in ways that are meaningful and useful to participants. Further, participants could return to and revise goal setting documents throughout their pre-service and beginning in-service years. For example, a student teacher might identify “critically examining curriculum” as an area of focus and work to both examine and adapt curricular materials with their attending teacher and on their own, perhaps starting with a single lesson or activity. As a student teacher transitions into a resident and takes on the responsibilities of a teacher of record, they could adapt this goal to include their planning and enactment of project and place-based units. Furthermore, TTS participants could identify supports that might help them reach their professional goals, such as case conferences with near-peers and co-planning or co-teaching with attendings.

6. Engage in ongoing reflective opportunities and feedback with attending teachers and attending teacher educators.

Lastly, building reflexivity and awareness of areas of improvement could prove useful in developing dual commitments of learning about ARSJ STEM teaching practice *and* improvement on practice. Such reflexiveness could be fostered through ongoing opportunities to reflect on one's practice, including analyzing the ways in which students are engaging with the teacher and their peers throughout the school year. Normalizing reflection and feedback is important in decreasing the likelihood of defensiveness and hesitancy to engage in learning opportunities made available within TTS model. Furthermore, it is important to note that reflection and feedback are to be considered an iterative process – both reflection and feedback opportunities should be followed by action, and such changes should then be reflected upon and again open to feedback and modification as necessary.

Reimagining TTS Attending Teacher Experience

As stated throughout this dissertation, attending teachers are critical to the support student teachers receive. Because most of one's pre-service training occurs in partnership with a mentor, TTS model should also consider how opportunities to learn ARSJ STEM teaching practices, and support others in doing so, are extended to attending teachers. It is important to note that the idealized TTS model attends to professional development opportunities for attending teachers to learn about ARSJ STEM teaching and improve on their practice. Although the virtual year of instruction prevented such a structure from taking place, its potential impact on future school years should not be discounted. Particularly, professional development opportunities for attending teachers could be aimed at discussing and providing feedback to student teachers and, to a lesser extent, residents around ARSJ STEM teaching practices. If we are expecting student teachers and residents to make use of ARSJ STEM teaching practices observation protocols and planning templates (as discussed above), then it is important to also

consider how attending teachers are making sense of and supporting the use of such materials. Furthermore, as participants experienced limited opportunities to observe ARSJ STEM teaching in practice, supporting the learning of attending teachers could also widen learning opportunities for student teachers and further connect the university and Fairfield contexts.

A second consideration is how the model can better structure and scaffold opportunities for conversations with attending teachers and other colleagues about ARSJ teaching. Data related to student teachers' experiences talking about race and racism with their attending teacher, Matthew, suggests that more could be done to scaffold such conversations amongst participants. Although student teachers felt they learned a lot about antiracist teaching from Matthew, they also felt that the subject was never truly explicitly addressed. This further highlights the need for additional scaffolding, and perhaps training, for attendings to talk about race and racism in the context of teaching and learning. According to Ladson-Billings (2018), race is a fully "funded" concept in our society, as everyone has developed conceptions around race, racism, and the stereotypical tropes that go along with them through societal messaging in media, familial relationships, and schooling. However, we have not, as the author points out, developed proper resources to talk about, address, and dismantle harmful conceptions around race and racism. While participants were committed to tenets of antiracist teaching and learning, there is still room to design learning opportunities to explicitly discuss and develop ARSJ STEM teaching practice.

Implications for Overall Programmatic Improvement

Observed differences across participants' engagement in TTS model supports are helpful in considering implications for design. As explored throughout the study, Kendall exhibited a very different experience in TTS model as compared to her peers. Not only did she resist TTS

supports in many ways, but she also self-selected out of the program the following year. Although we cannot deem this experience a success, we can learn a great deal from Kendall's engagement within TTS model. In particular, Kendall's experience demonstrates a need for more structured and required summer supports, and the development of ARSJ planning and assessment tools for attendings to use alongside participants. As shown in chapter 5, Kendall resisted supports to work on her science curriculum over the summer months leading into her first year of teaching. Even though these supports were incentivized through university course credits and monetary payment, Kendall continued to postpone meetings and described feeling too overwhelmed and uncertain about the virtual nature of the school year to get started. Since curricular development was a main concern to Kendall throughout the school year, it became clear through analysis that additional requirements around TTS supports could have aided Kendall in this regard. For example, as a condition of participation in the three-year residency upon graduation from student teaching, residents could be required to commit to participating in a series of compensated experiences to engage in curriculum development, study their own practice, and set pedagogical goals for the year. The timing of the experiences would need to be clearly established to allow the residents to pre-plan for evening, weekend, or summer activities. Although this work is currently conducted ad hoc across various attending teacher educator and resident pairs, creating a more systematic structure to these meetings could set the tone for the type of work participants are expected to do within TTS. The intention of such systematicity is not to become rigid or overbearing – teachers need and deserve time over the summer and throughout the school year to decompress and recharge. But, if TTS model promises to do something different in supporting beginning teachers in carrying out ARSJ STEM teaching, then

perhaps this starts with a commitment to work on curriculum when the typical demands and stresses of the school day are not present, such as the summer months.

Furthermore, if teachers do not wish to commit to this type of work, then perhaps TTS model is an imperfect fit. As previously stated, successful TTS participants appeared to exhibit dual commitments to ARSJ STEM teaching practices *and* continuous improvement on practice. In considering screening for potential TTS student teachers and residents, perhaps questions around baseline commitments to social justice and antiracism should be coupled with prospective teachers' mindset around observation, feedback, and improving their own practice. Unless participants are actively anti-ARSJ teaching practice, then the model should provide opportunities to learn about and develop such practices throughout their experience in TTS, as described above. And although I imagine the model to further scaffold participants' opportunities to engage in continuous reflection, feedback and professional development, such opportunities might be less effective for those who exhibit a more fixed mindset when it comes to teacher learning and growth. However, extending scaffolded opportunities to engage in such learning and growth to the pre-service training experience might better prime TTS participants to accept and utilize opportunities to learn ARSJ STEM teaching practices into their first years as a teacher of record.

Additionally, differences in how participants moved through TTS model suggest important considerations for the model itself. Findings indicate that participants came to TTS and approached opportunities to learn in varying ways. We expect human nature to play a role in these interactions, as not everyone is the same. If we expected and maintained a homogenous group of participants, not only would that be boring, but it would do little to work towards the development of a productively critical community of practice. Instead, differences in

participants' approaches to practice and teacher learning indicate the need to build structures that anticipate differentiated and targeted support. Just as one might build a structure to withstand an earthquake, TTS model should consider ways to move and sway that protects and maintains structural integrity. One such structure is utilizing the chief of residents position to build intergenerational and near-peer interactions towards productive critique. The chief of residents could observe residents' practice, co-plan, and discuss problems of practice in ways that might not be wholly available to someone in an attending teacher or attending teacher educator role. The chief of residents is closer to residents' practice in that they are colleagues in the same school environment, and they recently completed the residency experience. In the case of Kendall, she was asking for more interactions with student teachers, which could indicate a desire for more near-peer interactions rather than the support she was getting from "not-so-near" peers, such as attending teacher educators. Although Kendall received support from Stella through discussion in residency support meetings, leaning on Stella in the role of chief of residents could have better served her needs as a beginning teacher of record. This is not to say that the role of attending teachers and attending teacher educators is obsolete. Rather, it is about drawing on existing TTS structures to better differentiate support as needed and allow for "sway" within TTS model.

Lastly, structural features of TTS model need to attend to the time and resources needed for educators to fully commit to this type of work. In traditional school settings, educators are typically granted one planning period within their schedule of teaching responsibilities. This time is critical to educators' planning, assessment, and administrative work throughout the typical school day, as well as perhaps a few minutes to decompress or reset before the next group of students enter the classroom. Thus, asking or expecting educators to engage in the types of

learning opportunities imagined here might not fit within the confines of the typical school day. In the idealized vision of TTS model, residents are granted an additional planning period dedicated to time with TTS supports. This additional shared planning period could be used to engage in the types of supports and learning opportunities described above. However, due to district and school needs, additional planning periods have not always been protected or they are not aligned with the timing of their peers, creating scheduling difficulties to learning in intergenerational teams.

Future Directions for Research

In addition to the implications described thus far, this study presents important avenues for future lines of research. First, a limitation of the study was the inability to center youth's experiences working with and learning from new STEM teachers towards ARSJ aims. In future directions for research, youth voice could be centered and highlighted as focal data. In this youth-centric study, potential research questions could be:

- 1) How do youth experience pre-service and beginning in-service STEM educators attempts at learning to teach?
- 2) What do youth uphold as the most important things for their teachers to be able to do?
- 3) What do youth want their teachers to know about them?
- 4) What do youth already know about ARSJ STEM teaching practices?
- 5) What do youth want to learn about when it comes to ARSJ STEM teaching practices?
- 6) How do youths' experiences and choice shape pre-service and beginning in-service STEM teachers' instructional decisions around developing ARSJ STEM teaching practices?

Furthermore, because TTS has dual goals of student and teacher learning, these aims should not stop at the adults in the community. Rather, students should be agentic in their learning experience, as well as how their teachers are trained. Youth can be invited into conversations around pre-service and beginning teacher training, further understanding how someone becomes trained to be an educator. This opportunity could not only create stronger connections between educators and their students, but it could also work to further professionalize teaching and attract students from Fairfield as students of education, perhaps even returning to Fairfield to teach one day.

Secondly, the extended nature of TTS model lends itself well to thinking about longitudinal study of teacher development. As part of the larger project's data collection efforts, video and field note data of participants has been and continues to be collected over time. At the time of writing, Stella has completed her residency and now serves as chief of residents in her fourth year as a teacher of record, Iris is currently in her second year as a resident at Fairfield teaching engineering, Aaron is teaching mathematics at an educational institution out-of-state, and Kendall is teaching science at a nearby school, though she is no longer part of TTS. These trajectories provide rich context with which to continue studying teacher development over time. Particularly, Iris and Aaron's experiences both in and out of TTS space could provide insight into how TTS model prepared them for teaching along their current and divergent paths. Both participants' experiences post-student teaching could serve as a comparative case study on continuing teacher development within and apart from TTS. As chief of residents, Stella also has new responsibilities around supporting residents through monthly meetings and check-ins. One possibility for longitudinal study would be an exploration of her transition from resident to chief of residents, as well as her interactions with residents as a more expert near peer.

Third, studying teacher development within the model lends itself to an exploration of why teachers decide to stay at TTS and FHS. Although Kendall self-selected out of TTS, others have chosen to stay and continue their teaching careers at FHS. Furthermore, although there has been teacher turnover since FHS opened in 2019, no attending teachers have left. What does this say about TTS model and how it supports not only pre-service and beginning in-service teachers, but also veteran teachers at the school? Just as it is important to consider differences in how people arrive at TTS, it is perhaps equally important to understand what makes them stay. Efforts to understand such queries have begun at TTS through systematic interviewing of TTS participants at regular intervals each school year, with the potential for more focus on why they chose to teach at FHS and why they choose to stay. Further understanding attending teachers' reasoning could shed light on how to better support student teachers and residents, as well as perhaps how to extend such supports to the wider FHS community.

Last, it is important to consider what we can learn from Stella. Stella makes clear that the work of ARSJ STEM teaching is not impossible. So, what made her learning experience unique? Is her capacity to successfully navigate the perceived divide between ARSJ teaching practice and STEM concept and skill learning simply a function of teaching engineering, a subject with application and problem solving at its core? Did Stella have unique training experiences that supported such learning? Was Stella predisposed to such practices because of her experiences prior to teaching? In her current role as chief of residents, how might she support resident learning of ARSJ STEM teaching practices across STEM subject areas? Although this study cannot answer these questions specifically, such queries may provide directions for future research.

Conclusion

Conducting this study, I was consistently reminded of the complexities and nuances that come with not only defining but supporting the learning of ARSJ STEM teaching. Bringing together numerous educators from different backgrounds, institutional affiliations, and teaching experience presented challenges in creating a unified vision for ARSJ teaching practices at the school. Additionally, the backdrop of the pandemic school year provided an even more pronounced view of the challenges teachers face in learning how to teach. Put simply, this work is hard. Nevertheless, student teachers and residents participated in small communities of practice centered on dual goals of student and teacher learning. These dual goals are a vital and critical cornerstone to TTS community, as they ground the work we do together and sets TTS model apart from other models of teacher education. As a community, TTS is committed to long term goals of improving student learning outcomes through the improvement of teacher learning experiences in an embedded, extended, and place-based model of teacher education.

Furthermore, this work captured a specific moment in time in TTS model development. During the year of data collection, TTS was in its second year of operation and was under construction in both the physical and metaphorical sense. Physically, the historic school site was being retrofitted to accommodate the needs of K-12 students on Fairfield's campus. Metaphorically, TTS was constructing supports for pre-service and beginning in-service teachers to take part in a nascent partnership between the university and Fairfield. As I made a call for more longitudinal work to be conducted within TTS in previous sections, I am interested in studying how TTS itself develops over time.

Appendices

Appendix A: Resident Semi-Structured Interview Protocols

Fall 2020 Semi-Structured Interview Protocol

1. Tell me a bit about why you chose to become a teacher.
2. Tell me about why you chose to teach in [city] and at FHS specifically.
3. As you know, the Teaching School and FHS share goals around antiracist and social justice teaching. This is something we're going to focus on with our work together throughout the school year. At this point in time, how would you describe antiracism and social justice? What does it mean to be an antiracist and socially just teacher? What does it mean to be an antiracist and social just *science/engineering* teacher?
4. What have you learned about antiracist and social justice teaching throughout your time thus far at the Teaching School.
5. What are some opportunities to learn antiracist and social justice teaching that you've encountered throughout your time in the Teaching School? An opportunity to learn is any instance where you're learning about antiracism and social justice, whether this is a specific tool, such as a reflection or journal prompt, or a more informal conversation with colleagues or students. Describe a specific opportunity to learn, if possible.
6. How do you see yourself, or not, implementing antiracist and social justice teaching in your practice? What might an antiracist and social justice science/engineering classroom environment or lesson look like?
7. What more would you like to learn about antiracist and social justice teaching?
8. As of now, what is missing within the Teaching School to provide you opportunities to learn antiracist and social justice teaching? What might better support you in these efforts?
9. Anything else you would like to add?

Winter 2021 Semi-Structured Interview Protocol

1. How would you describe your teaching practice at this point in the school year?
 - a. Are there ways in which you feel as though your practice has changed/shifted? If so, provide an example.
 - b. Are there ways in which you feel as though your practice has remained consistent? If so, provide an example.
2. How, and in what ways, has COVID-19 impacted your practice?
3. As you know, the Teaching School and FHS share goals around antiracist and social justice teaching. This is something we've been focusing on in our work together in

- residency support meetings. What are the key elements in being an antiracist and socially just teacher?
- a. What might you consider key elements in being an antiracist and socially just *science/engineering* teacher?
 - b. Any examples from your practice?
 - c. How might this look different in other disciplines?
4. What are some things that have helped you learn this year?
 - a. Is there anything you can think of that would help you learn? What could you imagine might be useful in supporting the development of your practice?
 - b. Do you feel that COVID-19 has impacted your opportunities to learn antiracist and socially just STEM teaching? If so, how?
 5. I would like to talk for a moment about STEM literacy practices in your classroom. Before we get into details, how would you define literacy broadly?
 - a. How are you thinking about literacy in science/engineering/math?
 - b. How does literacy play a role in ARSJ STEM teaching?
 6. What are some things you'd still like to learn about in relation to your practice?
 7. Anything else you would like to add?

Spring 2021 Semi-Structured Interview Protocol

1. How would you describe your teaching practice at this point in the school year?
 - a. Are there ways in which you feel as though your practice has changed/shifted? If so, provide an example.
 - b. Are there ways in which you feel as though your practice has remained consistent? If so, provide an example.
2. How, and in what ways, has COVID-19 impacted your practice?
3. As you know, the Teaching School and FHS share goals around antiracist and social justice teaching. This is something we've been focusing on in our work together in residency support meetings. What are the key elements in being an antiracist and socially just teacher?
 - a. What might you consider key elements in being an antiracist and socially just *science/engineering* teacher?
 - i. Any examples from your practice?
 - b. How might this look different in other disciplines?
4. What are some things that have helped you learn about antiracist and socially just this year?
 - a. Is there anything you can think of that would help you learn? What could you imagine might be useful in supporting the development of your practice?
 - b. Do you feel that COVID-19 has impacted your opportunities to learn antiracist and socially just STEM teaching? If so, how?
 - c. What are some things you'd still like to learn about in relation to your practice?
 - d. Anything else you would like to add?

Appendix B: Student Teacher Semi-Structured Interview Protocols

Fall 2020 Semi-Structured Interview Protocol

“Grand Tour” Questions

1. How has your semester been working at FHS and in the Teaching School?
 - a. What were some of the “highs” and the “lows” of the semester?
 - b. How was it working with your attending mentor teacher this semester?
2. What were some of your biggest moments of growth?
3. What were some of the difficulties of working in the Teaching School and at FHS?
4. What might be additional supports that would help you as a student teacher?
 - a. What are some things you might need?
 - b. How can your attending mentor teacher help with this?
 - c. How can your field instructor support you?
5. What are you most looking forward to about student teaching?
 - a. What questions do you have about student teaching at FHS?
 - b. What are you hesitant or nervous about when it comes to student teaching?
6. What are your future goals for your teaching career?
 - a. Where, what, & in what context might you want to teach?

About previous STEM learning and Disciplinary Understandings

7. What would you say are the driving questions that underlie your discipline?
 - a. How is knowledge built in your discipline?
8. What were your experiences in STEM/social studies/ELA (specific discipline being certified) classes in high school?
9. What were your experiences in STEM/social studies/ELA (specific discipline being certified) classes in college?
10. Did you experience courses with project-based learning? If so, what did it show you about this kind of teaching and learning?
 - b. How are these experiences similar to or different from your experiences at FHS and the Teaching School?

Concepts of Teaching and Pedagogies

11. How have your experiences (previous learning/courses, personal experiences, industry experiences) influenced the way you think about teaching in your discipline?
 - a. How has the field placement at FHS and the Teaching School influenced how you think about teaching? How you think about your discipline?
12. As you may know, the Teaching School and FHS share goals around antiracist and socially just teaching. At this point in time, how would you describe antiracism and social justice?
 - a. What does it mean to be an antiracist and socially just teacher?

- b. What does it mean to be an antiracist and socially just *math/social studies/ELA* teacher?
13. What are some opportunities to learn antiracist and socially just teaching that you've encountered throughout your time in the Teaching School or the SOE? An opportunity to learn is any instance where you're learning about antiracism and social justice, whether this is a specific tool, such as a reflection or journal prompt, or a more informal conversation with colleagues or students.
- c. Describe a specific opportunity to learn, if possible.
14. What more would you like to learn, and what currently exists, or is missing, from the Teaching School to support you in these efforts?

Spring 2021 Semi-Structured Interview Protocol

“Grand Tour” Questions

1. How has your semester been working at FHS and in the Teaching School?
 - a. What were some of the “highs” and the “lows” of the semester?
 - b. How was it working with your attending mentor teacher this semester?
2. What were some of your biggest moments of growth?
3. What were some of the difficulties of working in the Teaching School and at FHS?
4. What might be additional supports that would help you as a new teacher?
 - a. What are some things you might need?
5. What are you most looking forward to about teaching?
 - a. What are you hesitant or nervous about when it comes to teaching?
6. What are your future goals for your teaching career?
 - a. Where, what, & in what context might you plan to teach?

About previous STEM learning and Disciplinary Understandings

7. What would you say are the driving questions that underlie your discipline?
 - a. How is knowledge built in your discipline?
8. What was your experience like with project-based learning at FHS?
 - a. What did this show you about this type of teaching and learning?
9. What questions do you have about project-based learning at this time?

Concepts of Teaching and Pedagogies

10. How have your experiences in the Teaching School influenced the way you think about teaching in your discipline?
11. As you know, the Teaching School and FHS share goals around antiracist and social justice teaching. This is something we've been focusing on in our work together in residency support meetings. What are the key elements in being an antiracist and socially just teacher?
 - a. What might you consider key elements in being an antiracist and socially just *science/engineering* teacher?
 - b. Any examples from your practice?
 - c. How might this look different in other disciplines?
12. What are some things that have helped you learn this year?

- a. Is there anything you can think of that would help you learn? What could you imagine might be useful in supporting the development of your practice?
13. Do you feel that COVID-19 has impacted your opportunities to learn antiracist and socially just STEM teaching? If so, how?
14. Anything else you would like to add?

Appendix C: Journal Entry Prompts

Date	Prompt
9/17/20	How do you use routines in your classroom? What are some routines you currently use with your students? What is a routine you know you need to establish this year, but haven't? What questions do you have about routines?
9/24/20	What are some strategies you have tried or used thus far for managing student engagement online? What are some challenges and/or successes you have experienced? What questions do you have about managing online student engagement?
10/1/20	What are some ways in which you've tried, or ideas you have, to engage students with text? How have you approached literacy assessment in your class thus far? What questions do you have about literacy assessment and supporting student engagement with text?
10/8/20	Based on your observation(s) of colleagues' classrooms (or your own classroom), how would you describe overall student engagement and motivation? What are you noticing as strengths and challenges to students' engagement online?
10/22/20	Think back to the co-observations you recently conducted with respect to student engagement and motivation. Is there anything that stood out to you that you have thought more about? Anything that you have incorporated into your own practice? Explain.
10/27/20	Think back to the reading you prepared for today (Darling-Hammond, 2017). What is at least one question you had while reading? What is at least one point of interest you identified? Explain why this section or passage resonated with you.
11/3/20	Reflecting on yesterday's professional development opportunities, what is one thing you learned that you would like to incorporate into your practice? Did anything surprise you? What questions do you still have?
11/17/20	<ol style="list-style-type: none"> 1. How does your own social location shape your mindset about teaching and learning, the students you serve, and the practices you enact? 2. What can you do to become a more critically conscious educator?
12/1/20	In general, how are you feeling about teaching/life at this point in the school year? Any particular challenges or successes? How are you thinking about wrapping up the end of the year before winter break?
12/7/20	[See, Think, Wonder protocol around two instructional artifacts from each resident]
12/14/20	Take a few minutes to review your goals document that you filled out at the beginning of the school year. How do you feel about these goals now? To what extent do you feel you've accomplished these goals? What adjustments do you feel might be necessary? What new goals would you like to focus on returning from break (as of now)?
1/19/21	Take a moment to think about the big, overarching learning goals for your students. When kids leave your class, what should they take with them? At this

	point in time, what do you think you've already spent time doing towards these goals, and what are the objectives you would like to attend to moving forward?
1/26/21	How would you like to focus our time together this term? In other words, how should we spend our time together? Are there specific topics, activities, or ideas that you would like to explore further?
2/2/21	Think back to [Matthew]'s video leading classroom discussion last week. What are some things that stood out to you? Is there anything you have tried, or thought about trying in your own practice? What questions do you have at this time about facilitating peer-to-peer feedback and academic discourse?
3/9/21	Reading: Delpit (1988). Choose at least three quotes or excerpts that stood out to you while reading. Then, document I think..., I wonder... about each.
4/13/21	How would you describe the current school culture at FHS? What are the qualities of a strong school culture, and what might you want to see at FHS? What is the relationship between school culture, student learning, and social justice?
4/20/21	Review the [district] evaluation rubric. What are some of the ways in which it captures equitable and just online teaching and learning? What are some ways in which it could be adjusted to better capture equitable and just online teaching and learning?
5/4/21	Complete the implicit bias survey. Were you surprised by your results? What are ways in which this bias might play out in your practice? Are there other biases that might occur in your practice? What are some ways in which we might address such biases?
5/11/21	Overall, how are you feeling about returning to in-person learning? What are some things you might be anxious or hesitant about? What are some things you might be excited about or looking forward to? Any ideas about how we can support you in this transition?
5/18/21	What are some ways in which you're seeing students need emotional support online? How are you considering emotional support for students when returning to the classroom? Were there any key takeaways from the article that shape how you're considering setting up supports for students as you transition to in-person learning?

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