1-5-2024

Exploration of Secondary Science Teacher Candidates' Ideological Shifts in an Initial Teacher Preparation Program

Claudia E. Hagan
Georgia State University

Recommended Citation

Hagan, Claudia E., "Exploration of Secondary Science Teacher Candidates' Ideological Shifts in an Initial Teacher Preparation Program." Dissertation, Georgia State University, 2024.
doi: https://doi.org/10.57709/36403660

ACCEPTANCE

This dissertation, EXPLORATION OF SECONDARY SCIENCE TEACHER CANDIDATES' IDEOLOGICAL SHIFTS IN AN INITIAL TEACHER PREPARATION PROGRAM, by CLAUDIA HAGAN, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree, Doctor of Philosophy, in the College of Education and Human Development. Education & Human Development, Georgia State University.

The Dissertation Advisory Committee and the student's Department Chairperson, as representatives of the faculty, certify that this dissertation has met all standards of excellence and scholarship as determined by the faculty.

_____
Patrick J. Enderle, Ph.D.
Committee Chair

_____
Renée S. Schwartz, Ph.D.
Committee Member

_____
G. Sue Kasun, Ph.D.
Committee Member

_____
Natalie S. King, Ph.D.
Committee Member

_____
Date

_____
Gertrude Marilyn Tinker Sachs, Ph.D.
Chairperson, Department of Middle & Secondary Education

_____
Paul A. Alberto, Ph.D.
Dean, College of Education & Human Development

AUTHOR'S STATEMENT

By presenting this dissertation as a partial fulfillment of the requirements for the advanced degree from Georgia State University, I agree that the library of Georgia State University shall make it available for inspection and circulation in accordance with its regulations governing materials of this type. I agree that permission to quote, to copy from, or to publish this dissertation may be granted by the professor under whose direction it was written, by the College of Education & Human Development's Director of Graduate Studies, or by me. Such quoting, copying, or publishing must be solely for scholarly purposes and will not involve potential financial gain. It is understood that any copying from or publication of this dissertation which

Claudia Hagan

NOTICE TO BORROWERS

All dissertations deposited in the Georgia State University library must be used in accordance with the stipulations prescribed by the author in the preceding statement. The author of this
dissertation is:

All dissertations deposited in the Georgia State University library must be used in accordance with the stipulations prescribed by the author in the preceding statement. The author of this

Claudia Erin Hagan
Department of Middle & Secondary Education
College of Education & Human Development
Georgia State University

The director of this dissertation is:

Patrick J. Enderle
Department of Middle & Secondary Education
College of Education & Human Development
Georgia State University
Atlanta, GA 30303

CURRICULUM VITAE

Claudia Hagan

ADDRESS: 1312 Lincoln Court Ave NE
Atlanta, Georgia 30329

EDUCATION:

Ph.D.	2023	Georgia State University Teaching & Learning: Science Education Atlanta, Georgia
M.A.T.	2013	Georgia State University Science Education Atlanta, Georgia
B. S.	2011	Berry College Environmental Science Mount Berry, Georgia

PROFESSIONAL EXPERIENCE:

2023 - Present	Chemistry & Physics Teacher Chamblee High School Chamblee, Georgia
2022 - 2023	Program Director, Induction Support Program College of Education and Human Development Georgia State University, Atlanta, Georgia
2018 - 2023	University Coach, Math, Science, & Social Studies Education College of Education and Human Development Georgia State University, Atlanta, Georgia

PUBLICATIONS:

Many, J. E., Tanguay, C. L., Bhatnagar, R., Belden, J., Griffin, T., **Hagan, C**., & Pettaway, C. (2023). Inspiring, Supporting, and Propelling Urban Educators: Understanding the Effectiveness of a University-Based Induction Support Program. *Education Sciences*, *13*(8), 770.

PRESENTATIONS:

International/National Presentations

1. Morandi, S.L., Southerland, S.A., **Hagan, C.**, & Kásper, V. (2023, June). *"The answer is your thinking…": One Teacher's role in Helping Students in Navigating their Epistemic Vexation*. International Society of the Learning Sciences (ISLS). Paper Presentation. Annual Conference. Montreal, Canada.

International/National Presentations

2. Pettaway, C., **Hagan, C.**, Griffin, T., Belden, J., Tanguay, C., Many, J.E., & Bhatnagar, R. (2023, April). *Inspiring, Supporting, and Propelling Urban Educators: Understanding the Effectiveness of a University-Based Induction Support Program*. American Educational Research Association (AERA). Paper Presentation. Annual Conference. Chicago, IL.
3. **Hagan, C.**, Griffith, T., Belden, J., Pettaway, C., Tanguay, C., Many, J.E., & Bhatnagar, R. (2023, March). *Developing Advocates for the Profession: Novice Educator Support during Induction*. Association of Teacher Educators (ATE). Paper Presentation. Annual Conference. Jacksonville, FL.
4. **Hagan, C.**, Morandi, S.L., Kásper, V., & Southerland, S.A. (2022, March). *"I wanted to break the pencil": The Teacher's Role in Reframing Moments of Epistemic Vexation*. National Association for Research in Science Teaching (NARST). Paper Presentation. Annual Conference. Vancouver, Canada.
5. **Hagan, C**. (2022, March). *Exploration of Secondary Science Teacher Candidates' Ideological Shifts in an Initial Teacher Preparation Program*. National Association for Research in Science Teaching (NARST). Poster Presentation. Annual Conference. Vancouver, Canada.
6. Morandi, S.L., **Hagan, C.**, Granger, E.M., Schellinger, J., & Southerland, S.A. (2022, March). *Exploration of Epistemic Orientation towards Teaching Science in a Longitudinal Professional Development Study*. National Association for Research in Science Teaching (NARST). Poster Presentation. Annual Conference. Vancouver, Canada.
7. Enderle, P.J., **Hagan, C.,** Morandi, S.L., Coker, R., Kásper, V., Vande Zande, D., Schellinger, J., & Southerland, S.A. (2022, March). *Tools for Observing Productive Talk: A Comparison of Two Protocols (RTOP/IQA-SOR)*. National Association for Research in Science Teaching (NARST). Paper Presentation. Annual Conference. Vancouver, Canada.

PROFESSIONAL SOCIETIES AND ORGANIZATIONS:

Active Membership

2022 – Present	Association of Science Teacher Educators (ASTE)
2022 – Present	Science Educators for Equity, Diversity, and Social Justice (SEEDS)
2019 – Present	American Educational Research Association (AERA)
2018 – Present	National Association of Research in Science Teaching (NARST)
2013 – Present	National Association of Science Teachers (NSTA)
2013 – Present	Georgia Association of Science Teachers (GSTA)
2013 – 2018, Present	Professional Association of Georgia Educators (PAGE)

HONORS, AWARDS, AND DISTINCTIONS:

2023 Distinguished Conference Paper - Accreditation, Assessment, and Program Evaluation in Education Preparation SIG
Inspiring, Supporting, and Propelling Urban Educators: Understanding the Effectiveness of a University-Based Induction Support Program
American Educational Research Association

EXPLORATION OF SECONDARY SCIENCE TEACHER CANDIDATES' IDEOLOGICAL SHIFTS IN AN INITIAL TEACHER PREPARATION PROGRAM

by

Claudia Hagan

Under the Direction of Dr. Patrick J. Enderle

ABSTRACT

Science teacher candidates (STC) enter an initial teacher preparation program with ideas of what it means to be an educator (Russel & Martin, 2014). Yet, they encounter ideologies about science education for all students that are often different from what they know (Arellano et al., 2016). This study explores how science teacher candidates respond to the ideologies of 3D teaching and learning and social justice. When presented together as one ideology, these ideas are intended to lead science teacher candidates to implement critical pedagogy. Teachers who use critical pedagogy seek to help students develop their identities, utilize community resources, and work to co-construct knowledge and action with students (Arellano et al., 2016). Teacher candidates encounter an ideology that asks them to question how their instruction and curriculum helps students understand themselves, others, power, equity, and anti-oppression (Muhammad, 2020). STCs' ideologies around what should and should not be talked about in the science classroom may be challenged. The purpose of this descriptive case study is to explore the alignment and/or resistance to critical science education ideologies for STCs in an initial teacher preparation program.

Using a conceptual framework that combines the Teacher-Centered Systemic Reform (TCSR) model (Woodbury & Gess-Newsome, 2002) and critical theory learning tasks for adults (Brookfield, 2005), the experiences of five science teacher candidates were explored. This descriptive case study took place during the 2021-2022 methods sequence. Three findings emerged from the study: (1) The consistency with which science teacher candidates' prior learning experiences are addressed in the ITP program influences their willingness to align with or resist program ideologies, (2) When placement schools' ideologies do not align with the ITP program, science teacher candidates are consistently positioned to critique their understanding of critical science ideologies, and (3) Teacher candidates combine the ideologies of social justice and 3D science teaching and learning into one through their own reasoning and practice. Implications include a need for explicit critical instruction and reflection for STCs, mentor teacher professional development, and consideration for one ideology grounded in critical science rather than two separate, as mentioned above.

INDEX WORDS: Initial Teacher Preparation Program, Science Education, Teacher Candidates, Ideologies

EXPLORATION OF SECONDARY SCIENCE TEACHER CANDIDATES' IDEOLOGICAL SHIFTS IN AN INITIAL TEACHER PREPARATION PROGRAM

by

CLAUDIA HAGAN

A Dissertation

Presented in Partial Fulfillment of Requirements for the

Degree of

Doctor of Philosophy

in

Teaching and Learning

in

Science Education

in

the College of Education & Human Development

Georgia State University

Atlanta, GA
2023

DEDICATION

For teachers:

those that came before,

those that are here now,

and those yet to come.

ACKNOWLEDGMENTS

In my culture, seven is an auspicious number. It has several meanings, but the one most relevant here is completion. This is poignant since my Ph.D. process has taken seven years to complete. Without the following folks, I might be still be here, but not as I am today.

To my students, past, present, and yet to come – The joy, love, insight, growth, and awareness you bring to my life never ceases to surprise me. During the lows in this process, the thought of being the best version of myself for you pushed me through. Thank you.

To my chair, Patrick – You found me when I was at my lowest and helped me see my genius. The belief, trust, and mentorship you have demonstrated for me consistently reminded me that I am somebody. As your first Ph.D. student, I hope that you are as proud of me as I am of you. Thank you.

To my husband, Michael – You more than deserve the little "h" in this Ph.D. From making sure I eat, to being a sounding board, to comforting me when I cried, to celebrating the little things, you have ensured my focus and ambition always came back to using my privilege to support others. Thank you.

To my committee, Dr. Schwartz, Dr. Kasun, & Dr. King – Each of you have had a pivotal role in my growth as a scholar and person. I am humbled to have worked and learned with you. The investment you have made in me and my work is immeasurable. Thank you.

To my dissertation compadre, Kásper – I was advised to find a peer who I could work with, share my thoughts with, and who would push me. I didn't think that would happen for me, until I met you. The endless hours of writing, late night texts about articles, and empathy you have shown me drove me to relish my work. Thank you.

To my therapist, Cassie – You were the lighthouse in the storm of my thoughts. The encouragement, calling in, and strategies to work through my mental health while completing this program have be instrumental in my success. You more than deserve a dot from this degree. Thank you.

Lastly, to my participants, Azula, Jacob, Madelia, Starr, and Tam – For years, I wondered who would enter my life and study. Your honesty, willingness, and inquisitiveness inspired me. This dissertation and degree would not exist without you. Thank you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 THE PROBLEM

Introduction

My head hurt. It hurt in the "what-the-Hell-Did-I-just-experience" type of way. It was the end of the first day of training as a science ambassador. I was selected by my district to learn about the new science standards being rolled out by the state. Earlier in the day, while waiting in line for a donut, I confidently told my peers that I was ready to deconstruct some standards! Little did I know I would be deconstructing my whole practice. Over the course of the next four days, headaches became a common experience, as did crying, unrestful sleep, and picking at my food. Why was I struggling so much? Why was I grieving over a professional development on the new state standards for science? Looking back, it was because I had been introduced to the concepts of science for all, science and engineering practices, crosscutting concepts, and disciplinary core ideas. My ideas about teaching science and my role as a teacher had been seriously challenged, and the new ideas had won. I began to question aspects of my practice that, until then, seemed like common sense. Why did I present vocabulary before teaching a concept? How come taking notes was central to every lesson? Was I the only holder of knowledge in my classroom? This level of discontentment led me to ultimately change my practice radically (Enderle et al., 2014). However, my practice was not the only aspect of teaching that changed for me. My ideology about what it means to be a science educator had shifted. An ideology is hard to discern, appears as common sense, and an individual is often unaware of it; however, ideologies inform everything an individual knows, does, and thinks (Bennett deMarrais & LeCompte, 1999; Brookfield, 2005; Žižek, 2008). New ideas became common sense, such as actively incorporating problems from my students' communities and letting students use their language to describe their ideas. I shifted from an ideology where I was the primary knowledge

holder in the classroom to one where that power was meant to be shared with my students. I moved from merely providing my students inquiry opportunities to devising chances to enact the role of scientists.

Having graduated from my initial teacher preparation program three years before in 2013, I just missed being exposed to *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council [NRC], 2012) and the *Next Generation Science Standards* (Lead States, 2013). These two documents are the latest in a string of national reforms made within science education. Ideologies about teaching science have been shifting since the 1950s, leading to *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (Framework) and the *Next Generation Science Standards* (NGSS). After the launch of Sputnik by the USSR, the United States government felt pressure to develop more scientists and engineers to ensure the country's dominance internationally (Ames, 2014). A little more than a decade after Americans landed on the moon, the National Commission on Excellence in Education conducted a study on the quality of American education. The commission produced a report, *A Nation at Risk*, that presented unfavorable findings (Bell, 1993). In 1989, another report, *Science for All Americans*, confirmed the worrisome findings of *A Nation at Risk*.

Part of Project 2061, *Science for All Americans* promoted literacy as the answer to the problems in America's science education. By prioritizing literacy, all students would become scientifically literate, making them better citizens of the country (Ames, 2014). Outlined in *Science for All Americans* were new ideas about what science education should be for students. This outline led to a shift in how Americans taught science. Quickly after *Science for All Americans* was released, the American Association for the Advancement of Science (AAAS)

worked to develop and publish the *Benchmarks for Science Literacy* in 1993. From this document and *Science for All Americans*, the NRC and the National Association for Science Teachers (NSTA) developed a set of science standards for the nation – *National Science Education Standards* (NRC, 1996). These standards, along with the *Benchmarks for Science Literacy* (AAAS, 1993), were used by states to develop internal science standards for fifteen years before a new report brought about the *Framework* (NRC, 2012). The *Framework* introduced yet another way of teaching students science and another shift in science education ideologies. This *Framework* informed the development of the *Next Generation Science Standards* (NGSS Lead States, 2013). By the 1980s, while the standards and documents had evolved, one idea persisted: Science is for all students.

Science for All

"America's future – its ability to create a truly just society, to sustain its economic vitality, and to remain secure in a world torn by hostilities – depends more than ever on the character and quality of the education that the nation provides for all of its children."

Rutherford & Ahlegren, 1989, p. xiii

With this call, the committee of Project 2061 (AAAS, 1989, 1993) introduced the concept of "science for all" into science education reform efforts. But what does "science for all" entail? After introducing this phrase and way of thinking, policymakers, curriculum developers, and researchers began to decipher what "science for all" means. Angela Calabrese Barton and Margery D. Osborne (2001) asked, "Who are we thinking about when we dream of science for all? What is a science for all like? Wouldn't a science for all look different from the education we are not trying to enact?" (p. 13). Similar to when I shifted my ideology about what it meant to teach science, researchers, policymakers, educators, and curriculum developers questioned ideas

that seemed self-evident. These questions and others like them drove the conversation around "science for all" in a new direction, understanding equity and how it differs from equality.

Equity has different and diverse meanings that can be inconsistent and sometimes contradictory (Secada, 1994). Here, I am using the idea of equity rooted in social justice. Walter Secada (1994) defined equity in education as "the scrutiny of social arrangements that undergird schooling to judge whether or not those arrangements are consistent with standards of justice" (p. 22). With this in mind, equity can be associated with justice and fairness. Equality, on the other hand, seeks to make education equal. This can look like having identical resources or access to equal funding (Calabrese Barton, 1998). Each child's context, school, and classroom are unique, so how does the educational system ensure equality for all of our children in science (Calabrese Barton & Osborne, 2001)? A focus on equality, however, is often at the cost of social justice for students from non-dominant groups (Lee, 1998). The invisibility of equity and social justice continued to be an issue throughout science education reforms (Rodriguez, 1997). The ideology of "science for all" continued to resonate during the formation of the Framework and NGSS (Lee et al., 2014).

The Next Generation Science Standards

April 2013 saw the publication of NGSS, ushering in a new way of thinking about how science is taught to students (Pruitt, 2014). Funded by the Carnegie Corporation of New York, the standards were developed using a two-step process. First, the NRC, NSTA, Achieve, and AAAS worked together to publish the *Framework.* The *Framework* outlined a vision for science education in the new century and what that meant for all students to be scientifically literate (Pruitt, 2014). Achieve led the second step, developing new performance expectations with 26 states to realize the vision outlined in the *Framework*. These became the NGSS documentation

meant to accompany the Framework (Pruitt, 2014). Newly included in the standards, three-dimensional teaching is a fundamental component of NGSS. This form of teaching employs each dimension of the *Framework*: science and engineering practices, crosscutting concepts, and disciplinary core ideas (NRC, 2012). Present throughout all dimensions of NGSS is the ideology that science is for all students.

All Standards, All Students

At the time of the development of NGSS, a diversity and equity team was formed to ensure the standards put forth would be accessible to all students. The team worked to provide teachers with tools and outlines to support them in creating equitable opportunities for all students to engage with science in the classroom (Lee et al., 2014). For example, the team created an appendix of seven case studies addressing different student demographics and another reviewing the new NGSS language (NGSS Lead States, 2013a). While there was progress toward including criticality within the NGSS, social justice, equity, and inclusion were still not completely visible. The work done by the diversity and equity team appeared in Hoeg and Bencze's (2017) document analysis of the NGSS. The second most prominent theme found is accessibility. In their analysis, however, Hoeg and Bencze (2017) found that accessibility is viewed as an "equal opportunity to obtain a science education relevant to the science workplace" (p. 290). They also found that "accessibility" was never defined in the NGSS documents. The writers of the NGSS chose to let the reader decide what accessibility means for themselves instead of being specific, like with the three dimensions or the science and engineering practices.

The Science & Engineering Practices

"Engaging in the practices of science helps students understand how scientific knowledge develops; such direct involvement gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world."

NRC Framework, 2012, p. 42

The science and engineering practices (SEP) are the first dimension of the Framework and NGSS. The SEPs "highlight the scientific practices commonly used by scientists" and the practices engineers use in their profession, such as designing and developing problem solutions (Rodriguez, 2015, p. 1031). Eight practices (Figure 1.1) are used throughout the NGSS to generate a constant connection between knowledge and practice (NGSS Lead States, 2013). Before NGSS, science classrooms' primary approach was scientific inquiry (Bybee, 2011). This form of teaching focuses on students practicing science and inquiry to learn about specific concepts, like photosynthesis. However, there were many definitions of inquiry used throughout the nation that resulted in it not being implemented as widely as needed (Bybee, 2011). Because of its ambiguous nature, inquiry fell into previously existing ideologies of US science educators. After NGSS, the specific nature of the SEPs have caused teachers to ask what it means to "do science."

The SEPs are a departure from previous standards documents. In the past, content knowledge could be assessed separately from students' ability to practice that knowledge (Lead States, 2013c).

Figure 1.1

Science & Engineering Practices

Source: NGSS Lead States, 2013c

In the NGSS, the intention is to assess students' performance of their knowledge. This focus comes across in Darren Hoeg and John Lawrence Bencze's (2017) document analysis of the NGSS. In their analysis, the concept most frequently encountered throughout NGSS is performance. The practices are specific ways in which students perform their knowledge. The specific nature of the SEPs makes sure there is limited interpretation of what is expected so that assessments are aligned with the standards (NGSS Lead States, 2013c). SEPs, therefore, can be seen as a refinement and addressing the issues encountered with scientific inquiry (Bybee, 2011). Despite the attempt at specificity, teachers still struggle to understand what certain practices mean and how they apply to students rather than educators (Dalvi et al., 2021).

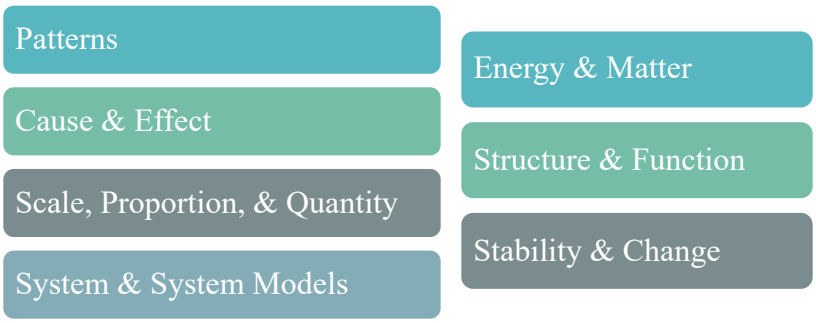
Crosscutting Concepts

> *"Crosscutting concepts have value because they provide students with connections and intellectual tools that are related across the differing areas of disciplinary content and can enrich their application of practices and their understanding of core ideas."*
>
> *NRC Framework, 2012, p. 233*

The crosscutting concepts (CCC) are the second dimension and the least clear or employed by teachers (Cooper, 2020). The CCCs (Figure 1.2) are not new in science education. They have appeared under different names in various science education documents. For instance, they are similar to the "unifying concept and processes" found in the *National Science Education Standards* (NRC, 1996). The CCCs have been part of science education ideology since *Science for All Americans* in 1989 (Duschl, 2012). The CCCs are themes or concepts that cut across the different disciplinary core ideas (Duschl, 2012). They are meant to "tie together the broad diversity of science and engineering core ideas in the curriculum" (NGSS Lead States, 2013d, p. 12).

Figure 1.2

Crosscutting Concepts.



Source: Lead States, 2013d

However, this dimension has proven to be the most difficult for instructors to implement due to

the less explicit nature of the CCCs (Arias & Fick, 2022). While much work has been done around the SEPs and disciplinary core ideas, the CCCs have had less attention (Cooper, 2020). There have even been calls to rebrand the CCCs as "styles of scientific reasoning" (Osborne et al., 2018). Despite this, the CCCs persist and are integral to the NGSS.

Disciplinary Core Ideas

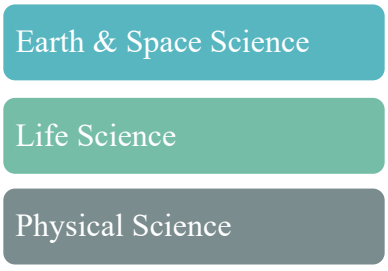
"The framework focuses on a limited number of core ideas in science and engineering both within and across the disciplines. The committee made this choice in order to avoid the shallow coverage of a large number of topics and to allow more time for teachers and students to explore each idea in greater depth."

NRC Framework, 2012, p. 2

The final dimension of the NGSS is the disciplinary core ideas (DCI). The DCI (Figure 1.3) are broken into three main areas of science. The concepts within each DCI are meant to be taught throughout K-12 education and are not broken into smaller sub-standards that are seen in some states' standards (Cooper et al., 2017). The adage "more is less" can be applied to the DCIs (Rodriguez, 2015). The ideas are meant to connect over time and across disciplines.

Figure 1.3

Disciplinary Core Ideas.



Source: Lead States, 2013e

For a concept to be included as a core idea, it had to meet two of the four criteria below (Lead

States, 2013b):

1. Have broad importance across multiple sciences or engineering disciplines or be a key organizing principle of a single discipline.
2. Provide a key tool for understanding or investigating more complex ideas and solving problems.
3. Relate to the interests and life experiences of students or be connected to societal or personal concerns that require scientific or technical knowledge.
4. Be teachable and learnable over multiple grades at increasing levels of depth and sophistication.

Understanding the criteria for DCI is essential since it determines what students should know and how they should be taught. Ideas about what science is influence how a teacher's content is shared and how much instruction students receive. In fact, NGSS states that "not all content is equally worth learning" (NGSS Lead States, 2013a, p. 3). Therefore, the ideologies of those involved in developing the *Framework* and *NGSS* have impacted what can be considered worthy of knowing in science. The way in which the NGSS language prioritizes elements encodes the writers' understanding of science and what science for all means. For instance, focusing on making the standards accessible rather than equitable is an example of how language and belief frame this document. Does accessible mean equitable to the writers? Regardless, the ideological positions of the educational elite selected to draft the NGSS had the power to influence the stances of others, including future teachers who would be guided by these standards.

Initial Teacher Preparation Programs

Initial teacher preparation is the system of learning and training future educators experience before becoming a professional certified teacher. Within initial teacher preparation (ITP), programs are categorized as either traditional or alternative (Grossman & Loeb, 2008). Graduates of traditional teacher programs complete a four-year degree in education, have had a long-term interest in becoming a teacher, and are typically young, White middle-class females (Guyton et al., 1991). Alternative teacher preparation programs were established in 1982 (Lederman et al., 2006). In response to a significant shortage of qualified teachers in high-needs areas like science, these programs were designed to produce qualified teachers within a single academic year to enter the workforce at an accelerated pace. Individuals participating in alternative teacher preparation programs are generally career changers, are older, and are more racially or ethnically diverse (Koballa et al., 2005). Lederman, Lederman, and Abd-El-Khalick (2006) believed the most significant difference between alternative and traditionally prepared teachers is that "alternative certification teachers are more committed to teaching, more willing to work in disadvantage areas, more willing to work with lower-ability students, and more diverse in terms of ethnicity" (p. 267). Findings presented by Carver-Thomas and Darling-Hammond (2019) support this claim. Carver-Thomas and Darling-Hammond (2019) found teachers from alternative teacher preparation programs are more likely to work in Title I schools, move schools more often, and are more likely to teach students of color.

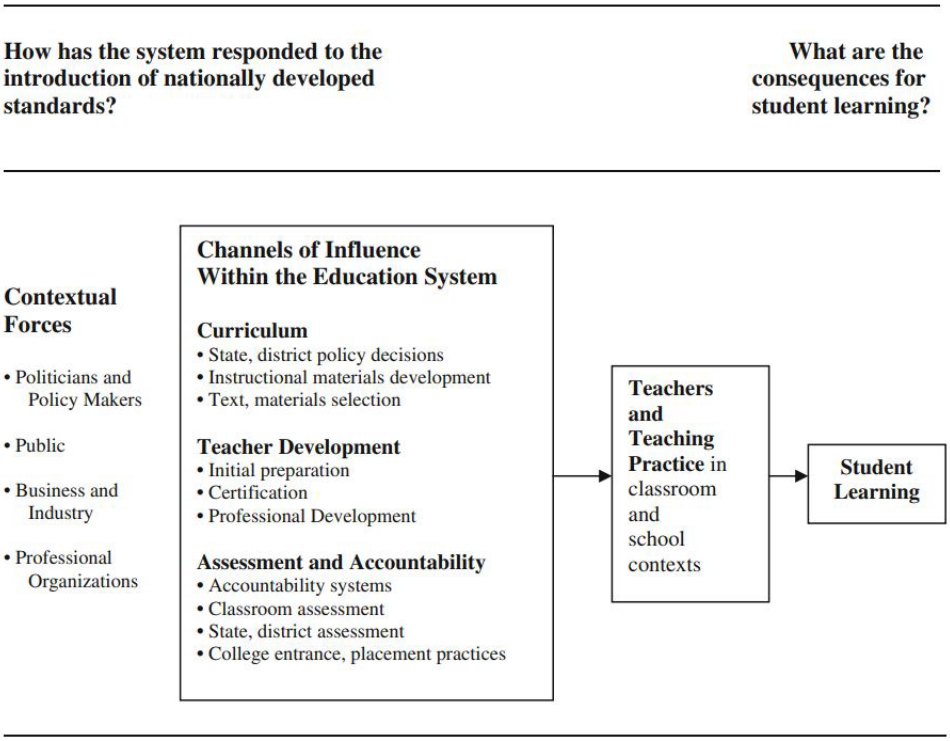
Many studies compare alternative and traditional teacher preparation programs and their graduates, but none focus on the different groups that enter alternative preparation programs (Shuls & Trivitt, 2015). Alternative has come to mean any pathway besides traditional, and with at least 130 different kinds of alternative pathways to certification, it has become a confusing

problem (U.S. Department of Education, Office of Postsecondary Education, 2006). In a review of science teacher preparation in the United States, Olson et al. (2015) had difficulty assessing the value of science teacher preparation due to the variability in certification requirements between states. Unfortunately, this difficulty persists throughout the country in analyzing teacher preparation programs and those who enter them (NRC, 2010). Specifically, for science ITP, the NRC cannot enumerate the instructions and programs experienced by science teacher candidates (2010). There is no common curriculum for the preparation of teachers or even best practices when designing a methods course (Clift & Brady, 2005; Wilson, 2011). Science teacher educators often develop courses based on their personal interests, biases, and program needs (Smith & Gess-Newsome, 2004). Missions for colleges and universities also determine the ideologies presented in ITP programs (Russel & Martin, 2014). Yet, research has found that teacher education "matters most" for enacting educational reform (Darling-Hammond, 2000; Darling-Hammond & Sykes, 1999; National Commission on Teaching & America's Future, 1996, 1997).

The Framework provides an outline for how influence works from a top-down perspective within education, particularly in science education (NRC, 2012). The three main routes from which information and knowledge flow are curriculum, teacher development, and assessment and accountability (Bybee, 2014). ITP programs are found under teacher development (Figure 1.4).

Figure 1.4

The influence of standards on the educational system.



Source: Bybee, 2014.

Within these programs, new beliefs and values within an ideology are shared with future teachers to inform their pedagogy. The ideals and practices taught to teacher candidates at the university in the ITP program are meant to support new teachers in the classroom. Specifically, in science, teacher candidates are taught how to implement the dimensions of NGSS and social justice into their teaching. Theoretically, these ideas then become common sense to the teacher candidates, their new ideology of science education informing all of their teaching decisions, practices, and beliefs about students.

Yet, Koballa, Glynn, Upton, and Coleman (2005) found that science teacher candidates do not necessarily adopt the beliefs or conceptions presented in their ITPs. Three science teacher candidates in an alternative teacher preparation program were interviewed about their

conceptions of science teaching throughout the school year. Koballa et al. (2005) make several conclusions from their results. First, teachers can hold both ideal and working conceptions about science teaching. These conceptions serve as a reference for their classroom practice. Secondly, novice teachers' conceptions of teaching science did not noticeably change during the investigation. These conceptions varied from who should control lesson content to whether student learning is active or passive and the role of the learner's existing science ideas. This finding suggests conceptions of teaching held by the participants were resistant to change, even in the face of instruction. Lastly, only one participant, Liza, had an ideal conception from the program's point of view. What caused only a single participant to enact practices aligned with the beliefs presented in her ITP?

When science teacher candidates enter an ITP program, they often think they know little to nothing about the art of teaching (Russell & Martin, 2014). Yet, science teacher candidates enter ITPs unaware of their initial beliefs about what they will learn around science instruction. They are even more "unaware that they were learning a great deal about how to teach science" while in school (Russell & Martin, 2014, p. 871). The experiences teacher candidates had while learning science in school shape their understanding and expectations of their classroom practice (Richardson, 1996). Underlying practices, beliefs, values, justifications, and explanations that teacher candidates bring into an ITP program are filtered through their ideologies (Hewson & Hewson, 1989). These ideologies are at work during their coursework and teaching internships. Frequently, teacher candidates "use the information provided in course work to confirm rather than to confront and correct their preexisting beliefs" (Kagan, 1992, p. 154). This observation supports Dan Lortie's (1975) study, which argues that teacher candidates' predispositions to teaching through their experiences as students are a much more powerful influence than either

preservice education or later interactions in the workplace. There are many studies on science teacher candidates' practices and beliefs, but studies examining their willingness to shift ideologies to what their ITP program presents are lacking (Loughran, 2014). This is especially true when NGSS is viewed as an ideology within science education.

Preparation to Teach Diverse Populations

In 2018, the most recent National Survey of Science and Mathematics Education (NSSME+) report was published (Banilower et al.). The results of the 2018 NSSME+ give stakeholders a chance to "examine the influences of new initiatives and policy shifts such as the NGSS" (Banilower, 2019, p. 201). One of the many areas studied is teacher preparedness. Science teachers are asked how prepared they feel about developing students' conceptual understanding and cultivating those students' interest in science. The 2018 NSSME+ report found that 33 percent of middle and 35 percent of high school science teachers felt prepared to differentiate science instruction for diverse learners. Fifteen percent of middle school and 18 percent of high school science teachers felt prepared to incorporate students' cultural backgrounds into science (Banilower et al., 2018). These figures are troubling and add to concerns that the ideology of "Science for all" is not found in initial teacher preparation programs.

Although teachers who graduated from an ITP program in the last five years have received more courses to support diverse learners, such as multilingual learners and students with learning disabilities, than their peers, teachers still struggle to support these learners (National Center for Education Statistics, 2021). Not only are teachers' students diverse in their abilities, but the United States (U.S.) student population continues to be more ethnically, racially, and linguistically diverse. Recent studies found over 50 percent of students identify as students

of color in the student population in the U.S. (African American/Black, Native American, Latin American, Caribbean, Asian/Pacific Islander descent, and two or more races; U.S. Department of Education, 2017). Yet these findings are not reflected in the teaching force, where 79 percent of teachers identify as White (U.S. Department of Education, 2017). Because of this, "teachers need to develop culturally relevant teaching practices that use [social justice teaching] principles to interrogate the social, economic, political, and ideological contexts of schooling and to act upon their power as change agents who can transform the world" (Ajayi, 2017, p. 52).

Encapsulated within critical pedagogy is Social justice teaching (Moore, 2008a). Teachers who use critical pedagogy seek to help students develop their identities, utilize community resources, and work to co-construct knowledge and action with students (Arellano et al., 2016; Calabrese Barton & Osborne, 2001). Teacher candidates usually encounter critical pedagogy in multicultural courses during teacher preparation (Moore, 2008a). Even so, critical science pedagogy is not traditionally found in a secondary science classroom (Arellano et al., 2016). This may be partly explained by Pohan's (1996) research, which found that students who bring strong biases and negative stereotypes about diverse groups will be less likely to develop the types of professional beliefs and behaviors found in a classroom utilizing critical pedagogy. Yet, even when students are open to implementing critical pedagogy, they still struggle to use it (Ajayi, 2017). Students may have an ideal belief of implementing critical pedagogy into their teaching and practice; however, due to different types of challenges, the pedagogy implemented is what they believe works for them at the time. Is this because teacher candidates also hold ideal and working beliefs around critical pedagogy in the classroom (Koballa et al., 2005)?

Purpose Statement

Learning to teach secondary science under NGSS requires teacher candidates to become fluent in the three dimensions of crosscutting concepts, core ideas, and science practices. It is important to note a key critique of the NGSS is how its focus on equitable actually means accessible (Hoeg & Bencze, 2017). This lack of clarity makes it easy for social justice and equity to become invisible within the NGSS (Rodriguez, 1997). This is one of many reasons why critical pedagogy is not often seen in science education (Arellano et al., 2016). Yet in order to teach science to all students, critical pedagogy must be employed in the classroom. While in ITP programs, teacher candidates began to reflect on their own experiences as students in order to reevaluate their understanding of what it means to teach science. This questioning and development of pedagogical identities can potentially cause a shift in ideologies around science education. The purpose of this study is to explore why science teacher candidates align and/or resist critical science education ideologies while in an initial teacher preparation program. Guiding this research are the following research questions:

1. Why do secondary science teacher candidates align and/or resist critical science education ideologies?
    a. How do personal factors of teacher preparation influence teacher candidates' shift with critical science education ideologies?
    b. How do contextual factors of teacher preparation influence teacher candidates' shift with critical science education ideologies?
2. What role do shifting ideologies have in secondary science teacher candidates' willingness to implement new instructional strategies in their classrooms?

Conceptual Framework

"[Theory] becomes a transformative perspective that shapes the types of questions asked, informs how data are collected and analyzed, and provides a call for action or change."

Creswell & Creswell, 2018, p. 62

This study is qualitative in nature. Qualitative research roots itself in inductive thinking, collecting descriptive data in natural settings, and seeking to understand a participant's point of view (Bogan & Biklen, 2016). In order to meet these criteria, I chose two theoretical frameworks in which to situate my research: 1) critical adult learning tasks (Brookfield, 2005) and 2) the Teacher-Centered Systemic Reform (TCSR) model (Woodbury & Gess-Newsome, 2002). These frameworks informed my research questions and the design of this study. I combined them to form the Critical Learning for Systemic Reform (CLSR) conceptual framework. This section outlines the critical adult learning tasks and the TCSR model. Then, I outline how these theoretical frameworks contribute to this Critical Learning for Systemic Reform framework.

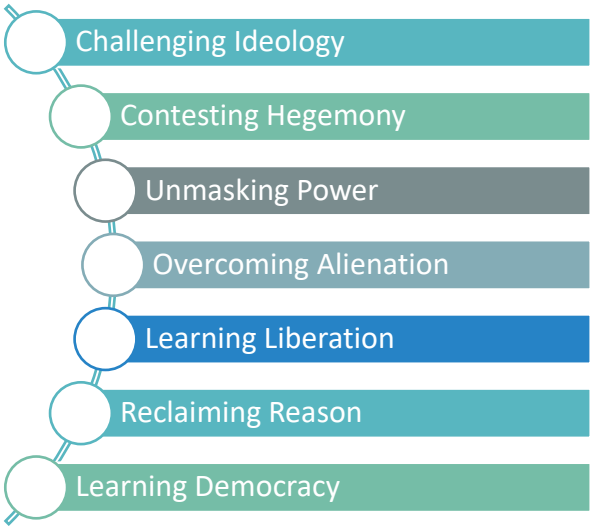
Critical Adult Learning Tasks

Stephen Brookfield (2005) aligns adult learning with the endeavor of becoming socially and politically aware of the inequities and systemic exploitation of others. He has termed this "critical theory of adult learning" (Brookfield, 2005, p. 2). There are seven learning tasks (Figure 1.5) adults need to participate in to develop social and political awareness fully: 1) challenging ideology, 2) contesting hegemony, 3) unmasking power, 4) overcoming alienation, 5) learning liberation, 6) reclaiming reason, and 7) learning democracy (Brookfield, 2005). Throughout the explanation of each critical adult learning task, Brookfield (2005) analyze instructional strategies adult educators use in the classroom, such as discussion and self-direct learning. In his analysis, Brookfield (2005) questions how these strategies aid or hinder learners when placed in a critical

theory perspective. I draw upon critical theorists for each chapter to inform this analysis and what the learning task looks like in the classroom.

Figure 1.5

The Critical Adult Learning Tasks



Source: Brookfield, 2005

In order to better understand the perspectives used for each chapter, it is essential to know which critical theorists lay the foundation for each critical learning task. Brookfield outlines challenging ideology in adult education with grounding from Max Horkheimer, Theodor Adorno, and Louis Althusser. Brookfield explores how adult learners and their educators can contest hegemony in the classroom with help from Antonio Gramsci's work. The role of power and how to unmask it from education systems to the individual classroom is told through Michel Foucault's writings on the topic. Erich Fromm's ideas inform the learning task of overcoming alienation. Herbert Marcuses' work is centered in the task of learning liberation. Finally, Jürgen Habermas' thinking is explored and expanded in the learning tasks of reclaiming reason and learning democracy.

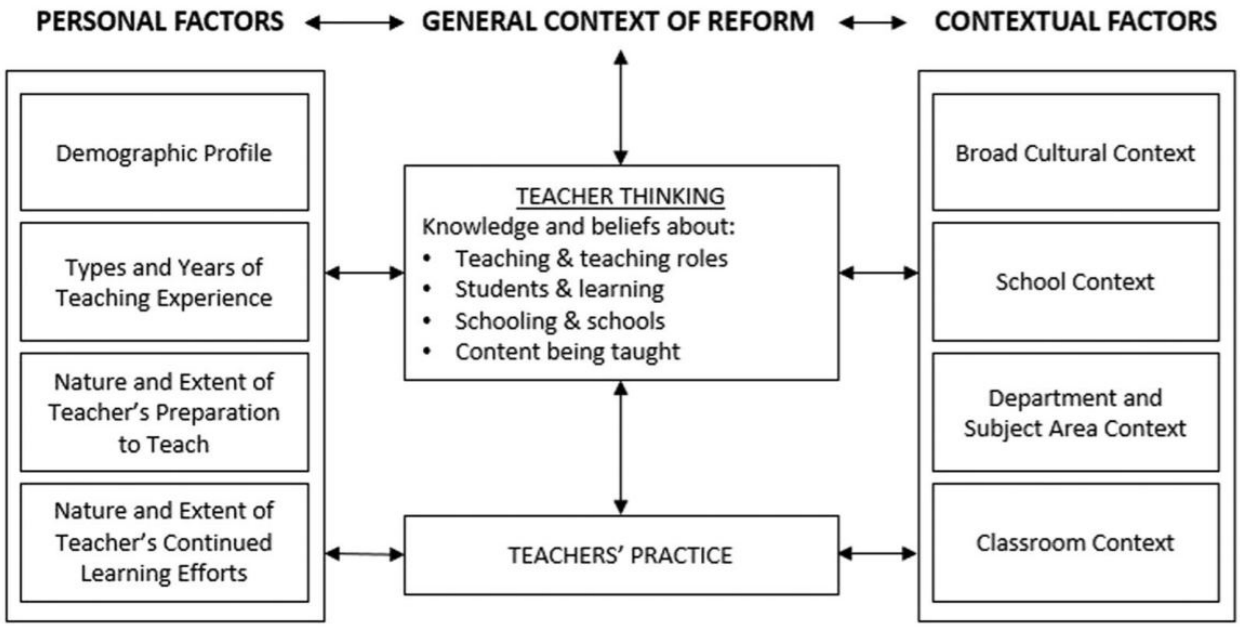
The critical adult learning tasks work together to develop individuals who are aware of the systems and their roles within them to bring about change. Brookfield (2005) views each learning task separately from the others, but together, they give the best chance for political awareness and critical thinking. For this reason, I focused on all seven critical adult learning tasks.

Teacher-Centered Systemic Reform Model

The Teacher-Centered Systemic Reform (TCSR) model was developed to demonstrate how teacher thinking is central to accepting or resisting 'reform' ideologies. Teacher thinking is related to and influenced by personal and contextual factors that are ultimately reflected in teacher practice (Woodbury & Gess-Newsome, 2002). The TCSR consists of four main domains: 1) personal factors, 2) contextual factors, 3) teacher thinking, and 4) teachers' practice (Figure 1.6). Personal factors encompass the experiences and identities that impact teachers' learning, such as years of experience and demographic information. Understanding the personal education experiences teachers have had and who they are helps contextualize their acceptance of new ideas around education (Gess-Newsome et al., 2003). The contextual factors reflect the structural and cultural aspects of the systems that teachers function within. The TCSR uses a funnel view of systems, starting with the community and extending to the classroom context. Structural factors, such as materials, schedules, and physical space, are considered in this category. Another important facet within contextual factors is the cultural context in which the teachers function. This includes departmental structures, the influence of administrative leaders and mentors, and the perception of the school's goals. The overarching theme of school culture is present within contextual factors (Woodbury & Gess-Newsome, 2002).

Figure 1.6

The Teacher-Centered Systemic Reform Model



Note: Adapted from Woodbury & Gess-Newsome (2002).

Contextual and personal factors work together to inform teachers' thinking about their role in the classroom, how their students learn, and what they should teach. Woodbury and Gess-Newsome (2002) outline five salient components of teacher thinking relative to altering their practice. These components are 1) teachers' knowledge and beliefs about their subject, 2) teachers' knowledge and beliefs about how students learn, 3) their ideas about teaching and teachers, 4) teachers' thinking about change, and 5) teachers' understanding and attitudes about the context of the systems they work in (Woodbury & Gess-Newsome, 2002). Teacher thinking and personal and contextual factors are all reflected in teachers' practice in the classroom. Conversely, the success and failure of students, classroom facilitation, and instructional strategies impact teachers' thinking and personal and contextual factors.

The TCSR model is intended to evaluate or develop reform efforts in education (Woodbury & Gess-Newsome, 2002). For this study, I used the TCSR model to evaluate how preservice teachers interact with ideologies in a reform-driven initial teacher preparation program. All domains of the model are employed throughout the study. I consider teacher practice, demographics, and teacher preparation, along with the five salient components found in teacher thinking in my process. Finally, all sections under contextual factors in Figure 6 are addressed. I primarily focus on how school culture and curriculum influence teacher practices and beliefs for contextual factors.

Critical Learning for Systemic Reform Model

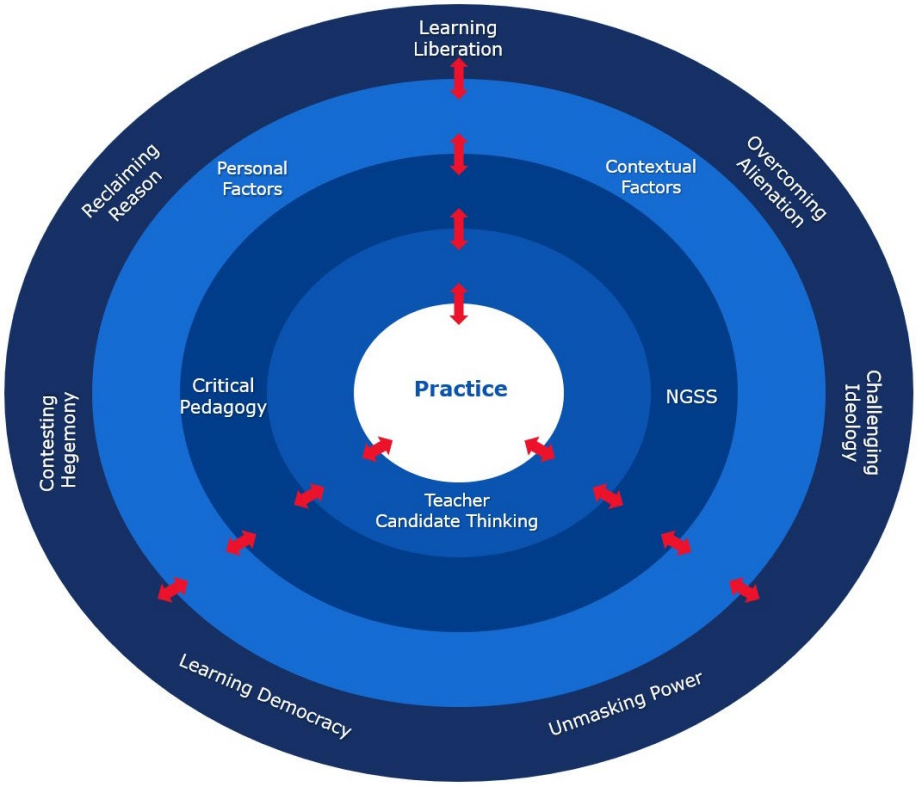
Elements of the critical adult learning tasks and the TCSR were combined to form the critical learning for systemic reform (CLSR) model (Figure 1.7). This model describes the relationship between critical adult learning and the factors influencing reform in teachers' classrooms. Even though this study focuses on secondary science teacher candidates, not teachers-of-record, this model is still applicable. These teacher candidates learned about reform-based educational ideologies while placed in school systems for their student teaching experiences that may or may not employ these ideologies. Through their student teaching, participants enacted practices informed by their thinking.

I think of this model as a slice of cheesecake, not just any cheesecake. I specifically think about my favorite type of cheesecake: Reese's Peanut Butter Chocolate. This cheesecake has layers of fudge cake, caramel, chocolate, gram cracker crust, and original cheesecake. In figure seven, the critical adult learning tasks form the ingredients of the cheesecake, like sugar and eggs. When mixed, these learning tasks affect the various layers of dessert. The domains from the TCSR are those elements. In my ideal cheesecake, layers of fudge cake, caramel, chocolate,

gram cracker crust, and original cheesecake become personal factors, contextual factors, educational ideologies, and teacher thinking. When I take a bite of the cheesecake, I eat all the layers together – not one at a time. The fork that enables me to take a bite of cheesecake represents teacher candidates' practices. Unlike a sandwich, I cannot pick the cake apart, removing the pieces I do not like. All ingredients and layers are in every bite. It is the same with my CLSR model. The model is holistic, seeking to understand how the different layers of the cheesecake work together to inform the taste and feel of a bite. Figure seven shows how every element (TCSR & educational ideologies) contains the same ingredients (learning tasks) and that they all influence each other. For this study, I will focus on specific elements to explore the alignment and/or resistance of science teacher candidates to critical science education ideologies.

Figure 1.7

The Critical Learning for Systemic Reform Model.



Significance of the Study

The heart of this research stems from wanting to understand the metamorphosis secondary science teacher candidates experience while engaged in an initial teacher preparation program that centers three-dimensional science learning and teaching for social justice. According to NGSS ideology, science must be taught to "all students" through the three dimensions of science and engineering practices, crosscutting concepts, and disciplinary core ideas (NGSS Lead States, 2013). This requires teacher candidates to be aware of the various contexts and systems their students navigate in ways that often challenge their perceptions of what it means to be a science teacher. Similarly, their interaction with the ideology of social justice and critical pedagogy gives student teachers tools to create a supportive environment and develop a drive to advocate for all students. However, ideologies are firmly cemented, hard to recognize, and even more difficult to shift (Bennett deMarrais & LeCompte, 1999; Brookfield, 2005; Žižek, 2008). The context of a science teacher candidate, both personal and professional, impacts their beliefs and practice about critical science education pedagogy (Woodbury & Gess-Newsome, 2002). My research is focused on exploring the development of justice-centered, critical, and racially conscious educators by understanding what factors cause science teacher candidates to accept or reject being an advocate for all students.

2 REVIEW OF THE LITERATURE

When I began to develop the ideas around this study, I was asked a seemingly simple question that blew my conceptual world apart: "What are you valuing?" Having to ask myself this question about my work was difficult. I struggled to find the center of this study. Then I was reminded of quote from bell hooks, "I came to theory desperate, wanting to comprehend – to grasp what was happening around and within me… I saw in theory then a location for healing" (1994, p. 59). I, like bell hooks, found theory as a place of healing and understanding. It helped me determine what I value in this study and what I am seeking to heal for myself through this work.

In this chapter, I explore different aspects of the theory behind the conceptual framework designed for this study. I first start with what I considered to be the ingredients to forming the components of the critical learning for systemic reform (CLSR) model: the adult critical learning tasks. I chose to center my conceptual framework within adult education due to the fact that at the end of the day, teacher candidates are adult learners. The experiences and process of learning that unfold during their work in an initial teacher preparation (ITP) program occur through the understanding of being an adult in society. From here, I expand into examining the different factors that compose the teacher-centered systemic reform (TCSR) model. These different components work together in the CLSR to present a holistic image of teacher candidates and the influences that impact their practice. Each of these components are formed from and within the adult critical learning tasks. Finally, I revisit the CLSR model to expand the different aspects of it in more detail. In order to fully explore the CLSR model, we must first start with the adult critical learning tasks.

Adult Critical Learning Tasks

"The categories we use to make sense of our experiences are shaped by dominant ideology. We cannot pursue liberation without uncovering and then challenging the hegemony of capitalist values and practices."

Brookfield, 2005, p. 6

In the United States, a person is legally considered an adult on their 18th birthday. Developmentally, people do not move out of adolescence into adulthood until around the age of 25 (Merriam & Bierema, 2014). For the purposes of this study, an adult learner is anyone over the age of 18 enrolled in collegiate classes. Therefore, those individuals enrolled in an initial teacher preparation (ITP) program are considered adult learners. The alignment or resistance secondary science teacher candidates experience towards the ideologies put forth by the ITP program informed this study. To understand how secondary science teacher candidates' learn and experience learning, I focused on all critical learning tasks. Stephen Brookfield (2005) aligns adult learning with the task of becoming socially and politically aware of the inequities and systemic exploitation of others. He has termed this "critical theory of adult learning" (Brookfield, 2005, p. 2). There are seven learning tasks adults need to participate in to develop social and political awareness fully: 1) challenging ideology, 2) contesting hegemony, 3) unmasking power, 4) overcoming alienation, 5) learning liberation, 6) reclaiming reason, and 7) learning democracy (Brookfield, 2005). In the following section, I explore the learning tasks to better understand how they work to support adults becoming aware of the systems and their enactment around them.

Challenging Ideology

To challenge ideology, a person must first know what it is. Ideologies are "systems of ideas and values that reflect and support the established order, and manifest themselves in our everyday actions, decisions, and practices" (Brookfield, 2005, p. 67). The first learning task focuses on adult learners identifying ideologies and then acknowledging their presence in the choices, decisions, interpretations, and judgments made daily (Brookfield, 2005). To develop this learning task, Brookfield draws upon the work of Max Horkheimer, Theodor Adorno, and Louis Althusser. Horkheimer and Adorno published *Dialectic of Enlightenment* (1972) which outlines how thought and reasoning have become instrumentalized. The instrumentalization of thought leads to reason only being applied to short term problems which works to promote the status quo. In *Dialectic of Enlightenment* (1972), Horkheimer and Adorno state that “thought becomes a commodity and language the means of promoting that commodity” (p. xii). In a capitalistic society, commodities come to define individuals’ self-worth and identities, along with other economic values. This is further explored in Horkheimer’s writing of *Eclipse of Reason* ([1947], 1974). The capacity for adults to reason is dominated by means-end thinking. The main application of reason is to gain short-term economic and social rewards. Words become tools to represent thought and reasoning. Horkheimer states “as soon as a thought or word becomes a tool, one can dispense with actually ‘thinking’ it, that is, with going through the logical acts involved in verbal formation of it” (1974, p. 23). When this occurs, it becomes easier to be reasonable or to conform with reality and the dominant group. Once this happens, the majority principal becomes the superior form of reasoning or thinking.

The majority principal assumes if most people agree with an idea then it is probably correct (Brookfield, 2005). These ideas about thought and reason are expanded by Louis Althusser.

Althusser explored ideology in his essay "Ideology and Ideological State Apparatuses" (1971). Althusser focuses on the implications ideology has on social systems. Ideology maintains the status quo because systems are accepted with no explanation or justification. Althusser views ideology as invisible but all-encompassing for people. They are unaware of existing within ideologies. For Althusser, an individual's actions reveal the ideology. Althusser (1971) identifies two socialization agencies that ensure ideologies are passed on and maintained: 1) repressive state apparatuses (such as law enforcement and legal system) and 2) ideological state apparatuses (like schools, religion, and media). Education works as an ideological state apparatus (ISA) by immersing students in ideologically determined practices. These practices appear rational and obvious, but they maintain the dominant ideology (Brookfield, 2005). However, resistance to these practices emerge through teachers who encourage students to question prevailing values and seek to help their students think deeply about the curriculum taught to them. These teachers push back against the educational system by challenging conventional wisdom and practice. Yet, the way in which these teachers were educated is not free from ideologically determined practices.

In adult education, educators also work within an educational system informed by the dominate group's reasoning. For instance, when graduate students are given a needs assessment to determine planning for instruction, educators fall into using the majority principal to inform their teaching. A needs assessment in this instance would be asking students what they believe they need to learn about more. By giving a needs assessment, adult educators are also making the assumption their students know what is best for them. However, students often determine their

areas of need by listening and comparing themselves to others in their peer group. This is a move to conform with their peers which limits resistance to ideologies (Brookfield, 2005). Another area under examination within adult education is the ideology of Whiteness and how its power and privilege undergird adult education practices (Colin & Preciphs, 1991; Johnson-Bailey & Cervero, 2000; Shore, 1997, 2000). Scipio Colin & Trudie Preciphs (1991) acknowledge the ideology of Whiteness has led to adult educators to be biased when interpreting learners' performances, judging others according to White skills and standards, and devising curriculum to reflect a White worldview. Sue Shore (1997) analyzes how non-White adult learners are positioned as deficient and disadvantaged and in need of attention by the dominant group. She also highlights the assumption made in adult education that all students want to achieve what the White center has (Shore, 1997, 2000). Juanita Johnson-Bailey and Ronald Cervero (2000) extend on Shore's work by stating adult educators fail to acknowledge the privileges and power White learners have. While adult educators work to become aware of the ideologies they function in and their impact, their students are also striving to navigate differing ideologies.

One of the more difficult ideological struggles teacher candidates experience are the "conflicting ideologies and related instructional practices as they move across university and school contexts" (Williamson & Warrington, 2019, p. 265). In particular, teacher candidates who are in university programs focused on anti-racist teaching, supporting multilingual learners, and push back on pedagogies that have historically marginalized diverse student populations experience the most dissonance with what they are learning versus what they are observing (Williamson & Warrington, 2019). These different ideologies can cause tension for teacher candidates in their learning. Thea Williamson and Amber Warrington (2019) found that English language arts teacher candidates experience different kinds of tension in their learning. One

participant, Sara, struggled with having embraced a different ideology about teaching than the other teachers at her placement school. This resulted in Sara joining, withdrawing, and then negotiating with the teachers at her placement. Yet, another participant, George, felt tension between learning theory and teaching methods with being able to have time to explore his own understanding of pedagogy. He made his own opportunity to explore this understanding outside of the ITP program by taking an independent reading course. Both of these students were challenging the ideologies presented to them and around them in some way. Another area this is seen in initial teacher preparation (ITP) programs is through language practices. Idelia Nuñez and Katherine Espinoza (2019) found that teacher candidates were able to better identify their own ideologies around bilingual teaching when observing an in-service teacher (mentor teacher [MT]). Teacher candidates whose ideologies aligned with their MT's practice were able to act out their own language ideologies. However, those whose MT's practice were in conflict with the teacher candidate's ideology, found ways to push back and implement their own language practices (Nuñez & Espnoza, 2019). This is reflective of the resistance acknowledged by Brookfield (2005) in challenging ideologies.

While there is work that focuses on how teacher candidates challenge ideologies, I was unable to find any specific to secondary science teacher candidates. Much of the research identified the challenges teacher candidates encountered between their ITP program's ideologies and teachers in their placement school. For instance, Barbara Crawford (2007) followed five science teacher candidates through their teaching experience in an ITP program. In her study, she focused on the beliefs and knowledge of the teacher candidates and their mentor teachers. While teacher candidates stated their mentor teacher's openness to trying new instruction approaches influenced their own willingness, Crawford (2007) found teacher candidates understanding of

the new approaches was also a large factor. Yet, the literature does not speak to the interactions teacher candidates have with their own ideologies and their ITP program. The literature is also sparse looking at how personal factors influence teacher candidates' acceptance or rejection of ideologies presented to them. For instance, neither studies presented above sought to understand why teacher candidates aligned with or resisted the ideologies of other teachers in their placement school. Nor did they explore other experiences the teacher candidates had outside of the ITP program that influence their ideologies. Once students are able to acknowledge ideologies, they can begin to examine how hegemony impacts their lives.

Contesting Hegemony

Hegemony is a process that causes individuals to be oppressed through their own beliefs and practices while elevating those with power (Brookfield, 2005; Marx & Engels, 1970; West, 1982). The second adult learning task outlined by Brookfield (2005) focuses on thinking critically about power and control, learning how to recognize ones' class position, and true political interests. This learning task is based in the work of Antonio Gramsci. Gramsci developed the idea of hegemony while in prison for being a threat to fascist Italy (Brookfield, 2005). He built upon the ideas of Marx, Machiavelli, and Nietzsche that center around power and culture. Hegemony is derived from the Greek word "hegemon" which means leader. This term is often related to absolute power and was used to describe Sparta and Athens (Ives, 2004). Keeping this in mind, hegemony is when the elites use their power to control aspects of culture. It can be difficult to identify hegemony because it can be hidden in cultural texts. Powerful ways hegemony is utilized can be found in language, traditions, and norms of society (Gramsci & Buttigieg, 2002). However, Gramsci argues there is a negotiation that takes place between the elites and non-elites or the producers and consumers (Storey, 2018). Hegemony "works when

people actively welcome and support beliefs and practices that are actually hurting them" (Brookfield, 2005, p. 94). Because of this, there is a strong link between hegemony and ideology. Marx and Engels (1970) outline the concept of ideology as how the ideas of the elite become the ideas for all. Hegemony is embedded in the systems, practices, and behaviors people function in every day. In this sense, ideology becomes hegemony when dominant ideas are present in all aspects of life for an individual (Brookfield, 2005). This can be seen in education.

Brookfield (2005) outlines one way how educators build their own ideological prisons and willingly stay in them through hegemony. In the field of education, the belief of answering a call and participating in an altruistic profession becomes hegemonic when it causes teachers to take on responsibilities and duties that exceed their capacities. For instance, when a professor volunteers to teach an extra class so the students in that course do not have to experience a subpar professor or when a teacher takes on a chair position to ensure the committee is able to fulfill their duties rather than let someone known to do the bare minimum be chair (Brookfield, 2005). The exploitation and manipulation that teachers agree to becomes a sign of commitment to their vocation and students. Learning to recognize and contest hegemony is contextual and relational. Nicky Duenkelt, Judy Pratt, and Julie Sullivan (2014) explore learning and contesting hegemony as adult educators through cooperative inquiry. As a group, seven adult educators set out to contest hegemony in their lives and practice. One of the of main ways they found hegemony impacts adult educators is through imposter syndrome. The self-doubt experienced by these educators was grounded in the belief and cultural norms of what and how they should conduct themselves as academics and teachers (Duenkelt et al., 2014).

The oppression exerted on them by their roles, cultural norms, and relationships lead to feelings of anxiety and self-doubt. The role of hegemony within institutions and society not only impacts the teaching experiences of adult educators, but also teacher candidates.

An attempt to contest hegemony in ITP programs can be seen through courses around diversity, inclusion, justice, and equity (Bullock & Freedman, 2006; Deroo & Ponzio, 2021). These courses may focus on specific topics such as language (Deroo & Ponzio, 2021), race (Bullock & Freedman, 2006), and disability (Bullock & Freedman, 2006). Teacher candidates are often female, White, and from middle-class families (Marom, 2019). Because of this, the forms of hegemony teacher candidates often interact with are those around monolingual speakers (García, 2009) being unaware of their own racial identity (Powell, 1997), and cling to and defend discourses of privilege (Pohan & Mathison, 1999). Matthew Deroo and Christina Ponzio (2021) taught courses at two separate universities focusing on recognizing K-12 students as having agency in their learning by using their experiences to support learning in language and literacy. Each course challenged teacher candidates to think critically about social movements ability to shape teaching and learning by using tenets of critical multilingual language awareness. Their findings show teacher candidates are able to connect language with identity and that linguistic hierarchies are socially constructed. This demonstrates teacher candidates are able to recognize hegemony. However, many teacher candidates oversimplified the impact language has politically, on belonging, and on identity.

The varied ways in which teacher candidates respond to contesting hegemony is seen in Patricia Bullock and Debra Freedman's (2006) study that seeks to understand how teacher candidates respond to diversity-focused course curriculum. Their findings revealed amongst 42 participants, students either connected to the diversity-focused curriculum, struggled to

understand diversity-focused issues as societal issues, or completely resisted the curriculum. Those who connected with the diversity-focused curriculum grounded their learning in their own experiences and were open to recognizing hegemony in their own lives. Teacher candidates who struggled with the curriculum were concerned about job security or confronted with their own beliefs. Bullock and Freedman (2006) use Ore and Kurtz's (2000) notion of stoppers. Stoppers are "mechanisms which reward conformity and punish or discourage nonconformity" (p. 588). The resistant teacher candidates lacked experience with individuals from marginalized communities and were not open to learning because they believed they already "knew everything" (Bullock & Freedman, 2006, p. 145). Bullock and Freedman (2006) found the order in which topics were presented in class to be imperative. Focusing on students with disabilities, moving to class, then sexual and gender identity, and ending with race, supported teacher candidate connection to each topic rather than resistance.

Each of these articles focuses on how teacher educators have supported teacher candidates to become aware of hegemony and its role in the classroom. Yet, they do not explore how this awareness impacts their students' practice inside a classroom. While each article also includes science teacher candidates, they do not specifically point out any subject-based interactions with hegemonic ideas. For instance, it is not clear if Deroo and Ponzio (2021) discuss science specific language issues with their students. Each study also focuses on how White teacher candidates react and understand hegemony within education. None of the studies I read highlighted how teacher candidates of color interact with or contest hegemony. By examining how hegemony works in teacher candidates' experiences as students, the role of power becomes more evident.

Unmasking Power

Michel Foucault (1982) defines power as more than interactions in relationships; it is how certain actions modify others. Unmasking power occurs when adults recognize they are agents of power, constantly channeling disciplinary power (Foucault, 1982), but they also possess the capacity to undermine dominant power relations (Brookfield, 2005). Foucault states that all individuals are vehicles of power which calls into question how a dominant group maintains hegemony over others. Foucault seemingly answers this question through the concept of disciplinary power. This form of power originated in the eighteenth and nineteenth centuries when imprisoning criminals rather than torturing or publically killing them became more common (Foucault, 1977). Disciplinary power is wrapped up in self-surveillance which helps an individual maintain the norms set forth by culture and institutions like schools. Other facets of disciplinary power are examination and normalizing judgement (Foucault, 1977). By exercising disciplinary power, individuals conform to systems and behaviors that maintain hegemony. Within critical theory, power is also exercised in two other ways: repressive and liberatory (Foucault, 1982). Repressive power constrains and coerces individuals to its will. Liberatory power animates and activates others to take control of their lives and is often in work that counters hegemony (Brookfield, 2005). Both forms of power are present at all times (Foucault, 1982). Liberatory power should be the intention of adult education (Kreisberg, 1992).

A main aim of adult educators is to have “power with” rather than “power over” their students (Kreisberg, 1992). By seeking to empower their students, adult educators implement practices believed to lead their students toward enacting liberatory power. This can be seen in having group discussions, learning journals, and self-directed learning contracts. These specific approaches are considered liberatory since they give power to students. While adult educators

may believe they have created spaces and learning opportunities of freedom uncontaminated by power relations, power is always present. Even when adult educators ask their students to develop their own curriculum, lead classes, and determine their own assessments, power relations and disciplinary power are still enacted (Brookfield, 2005). For instance, Jennifer Gore (1993) exposes the reality of power relations and disciplinary power during class discussions. While adult educators may view discussions as a liberating experience, for students it can be anything but that. Gore makes the point for students who are different from the majority in the class in either physical appearance, form of dress, native language or are intimidated by jargon can come to dread discussions. This experience can become not only painful and harmful, but also oppressive (Gore, 1993). The pressure to contribute can lead students to experience repressive power rather than liberatory power.

Oftentimes in ITP programs, teacher candidates experience power in different ways. Within their university classes, power relations can impact their learning around social justice (Ricks & Yenika-Aghaw, 2021). During Paul Ricks' course in children's literature with undergraduate elementary teacher candidates, he encountered multiple tense interactions with students around representation and messages found in picture books. Over the course of reading three picture books, students participated in group discussions. The books related to topics of class, gender, and race and were presented in a class of predominantly White students. During discussions, Ricks and Yenika-Aghaw (2021) found the responses of more dominant and authoritative participants like a "double-edge sword" (p. 8). While these students help move the class toward understanding the text, they also discouraged other students from participating by refusing to compromise or negotiate. While an adult educator can intervene in this situation, teacher candidates have to navigate their own disciplinary power during practicum (Lilach,

2019). Practicum is the part of an ITP program were teacher candidates are placed in a school in order to spend significant time in the classroom. They are supervised and mentored by an experienced teacher (mentor teacher) and are required to plan and instruct students in the classroom. Practicum is a key "experience for pre-service teachers [teacher candidates] to enhance their knowledge, skills, and critical awareness" (Zeichner, 2010, p. 232) and is considered to be the "most important component of their degree and the cooperating teacher [mentor teacher] as critical to their success in the degree" (Clarke et al., 2014, p. 163). Marom Lilach (2019) researched the different dilemmas related to power teacher candidates experience during practicum. She found teacher candidates struggle with 1) navigating power relations with in schools, 2) conforming with school culture and practice, and 3) gossip and cliques in a school. Specifically, teacher candidates felt tension between implementing practices, theory, and strategies focused on social justice and new curriculum in the classroom. Often, teacher candidates would enact disciplinary power to conform to what their mentor teacher, other instructors, and school administration accepted as appropriate for the classroom.

Foucault (1977) makes it clear that power is omnipresent and enacted in various ways. Teacher candidates experience power relations, disciplinary, repressive, and liberatory power throughout their ITP program. However, each individual will interact with these forms of power differently based on their positionality. This can be seen in how discussions can be repressive and liberatory while individuals navigate power relations and manage their own disciplinary power. Yet, none of the studies presented focus on individual students or students of color. While Lilach (2019) examines the role of power in practicum, she does not attempt to analyze the impact power has on students' teaching or experience in the ITP program overall. My study focused on teacher candidates from various backgrounds and follow them through two courses,

practicum and teaching methods, that are closely linked. It also highlighted a specific group of teacher candidates: those wishing to teach secondary science. Unlike these studies, the focus on science where new curriculum is implemented may bring a new aspect of disciplinary power into the teacher candidates learning experience. Hopefully, unmasking power is not where teacher candidates' critical learning ends. When teacher candidates begin to understand and see power structures, they often can begin to feel alienated.

Overcoming Alienation

The concept of alienation in critical theory developed in Karl Marx's (1992) *Economic and Philosophic Manuscripts*. In this work, Marx (1992) wrote about the *Entfremdung* or alienation theory, which addressed the idea of how individuals become estranged from themselves. Marx put forth that individuals become alienated when they are unable to realize their creativity in the workplace or when work leaves individuals too tired to explore their creativity (Brookfield, 2005). Alienation is dangerous because it stands in the way of freedom. Since alienation limits the choices one can make, it is antithetical to freedom (Brookfield, 2005; Marx, 1992). The social critic Enrich Fromm focused his work towards understanding why humans would turn away from freedom and towards fascism or totalitarian communism. Because of this, much of his work tackled the concept of alienation, how it occurs, and what individuals experience when they seek to overcome it. In Fromm's work *Escape from Freedom* (1941), he put forth alienation is a result of "an unwillingness of people to take responsibility for their own actions" (Brookfield, 2005, p. 52). This happens because individuals are fearful of freedom and the responsibility it holds. The most common response to becoming aware of freedom is the process of automaton conformity. This process occurs through social manipulation to be the same as the majority rather than free (Fromm, 1941). They lose

originality of thought and decisions (Fromm, 1956a), suppress critical thinking (Fromm, 1941), and cede responsibility for developing conscience (Fromm, 1956a). However, overcoming alienation is possible when an individual learns to have a structuralized view of the world. By being able to see how their decisions are framed and influenced by broader social structures and economic forces, adult learners build an awareness of how ideologies, cultures, and economics work to shape their lives and others (Brookfield, 2005).

The goal of adult education, in Fromm's view, is to assist adults in breaking away from the illusion that their lives and alienation are not tied to social arrangements. The critical adult learning task of overcoming alienation occurs when an individual learns to have a structuralized view of the world. Fromm (1976) suggested this could happen through discussion groups where members are willing to support each other in their learning. This interaction is crucial to adults setting their ego aside and developing "the knowledge that one's decisions has an effect" on others (Fromm, 1976, p. 179). By understanding this, it will support adult learners in developing their awareness of how their ideologies, culture, and economics shape others' lives, as well as, their own. Discussion groups that foster this environment can only take place when an adult educator employs a loving pedagogy (Fromm, 1956b). Fromm explores the importance of a loving pedagogy in his work *The Art of Loving* (1956b). To teach with loving pedagogy, an adult educator must overcome "a narcissistic preoccupation with one's own judgements and interpretations" (Brookfield, 2005, p. 177). Felicia Moore Mensah (2019) saw how adult education not taught with loving pedagogy could prolong alienation in her study following a Black science teacher candidate, Michele. Over the course of her ITP program, Michele struggled with how her professors approached issues like race, identity, and education. She often felt like her professors stereotyped her by believing "all Black people are the same" (Mensah,

2019, p. 1429). Michele also found her assignments meaningless and unable to connect them to her personal experiences. Her struggles with how her professor approached their classes and ways of teaching furthered Michele's alienation within the ITP program leading her to struggle with the decision to become a teacher. Unfortunately, Michele's experience with alienation is not unique within teacher education literature.

Teacher candidates who are not the majority within their ITP program often experience alienation. Non-White women teacher candidates must ignore their own ideologies, culture, and economic experiences to align with the majority in the process of automaton conformity. In the introduction to a special edition of *Equity and Excellence in Education*, Tambra O. Jackson and Rita Kohli (2016) examine the state of teachers of color. Through an examination of literature, they found the majority of literature reveals teacher candidates of color experience alienation in their ITP programs, specifically towards developing into teachers who effectively serve historical minoritized communities. For example, Jackson (2015) found teacher candidates of color felt their professors were afraid and unwilling to center socially just pedagogy like culturally responsive pedagogy in their courses. Participants also felt professors in their ITP program were dismissive of their cultures and ideologies leading the teacher candidates to experience alienation from themselves. Nquyen (2008) explores the practicum experiences of five Vietnamese American teacher candidates. All of the teacher candidates experience alienation throughout their student teaching in various ways. They struggled with the cultural differences, in particular with respect in the classroom. Those who had more experience with the Vietnam school system felt more alienated in practicum due to their expectation of reverential respect for the teacher that did not occur. Participants also struggled with how being women in their role influenced their ability to have inherent respect given to them in the classroom. On the

other hand, Çağlar's (2013) study on the relationship between alienation and teacher candidates' attitudes toward the teacher profession reveals male teacher candidates experience alienation at higher rates than female teacher candidates. The above studies demonstrate that teacher candidates who do not align with the majority found in ITP programs experience alienation at some point.

The focus of the literature in teacher education that addresses alienation seeks to explore the counter-stories of those who push back on the majority. These articles are insightful towards how to improve ITP programs and better support students who are from historical minoritized communities towards becoming educators. A common thread in these articles is their focus at primarily White institutions that are not centering justice-oriented pedagogies. In contrast, this study takes place at a predominantly Black institution where anti-racist pedagogies are at the heart of the ITP program. This study adds to the literature by exploring how science teacher candidates, in particular, experience alienation in this unique context. While this study did have a participant who is Black and one that is Vietnamese, it also included participants from the LGBTQ+ and Indian communities. The combination of teacher candidates with diverse backgrounds are not common when exploring alienation in ITP programs. By learning liberation, teacher candidates will be able to experience the world in a new way.

Learning Liberation

Liberation occurs when one overcomes oppression. Herbert Marcuse's work centers around the belief that individuals learn servitude and enjoy the oppression they function in. In his work One Dimensional Man (1964), Marcuse addresses the concept of one-dimensional thought. Used to control others, one-dimensional thought occurs when people focus on how to make the current systems perform more effectively. When this happens individuals "assume that all is for

the best in society, that things are arranged the way they are for a good reason, and that the current system works for the benefit of all" (Brookfield, 2005, p. 190). In order to not challenge the system, adults are taught to keep their thinking within fixed boundaries that causes one-dimensional thought to be circular even when it appears divergent (Marcuse, 1964). Language is where it is easiest to recognize one-dimensional thought. For instance, the usage of terms like "fake news" or "fair and unbiased" reporting cement one-dimension thought. These terms shut down any chance of divergent thinking or critical analysis (Marcuse, 1964). In order to overcome this oppressive thinking, individuals need to experience autonomous thought and creativity (Marcuse, 1964). The way to liberation from oppression is paved with intense experiences with art. These experiences can cause individuals to feel estranged from their reality of daily life. Once the feeling of estrangement occurs, individuals can become politically aware (Marcuse, 1972). Not only is art a way of learning liberation, but the usage of a new language is as well (Marcuse, 1969). For instance, teacher candidates using asset-based language rather than deficit-based language for describing their interactions and thoughts about students can be a form of liberation. The adult learning task of learning liberation calls for a change in the way individuals experience the world through thought, language, and art (Brookfield, 2005).

Marcuse challenges what liberating adult education means for educators. Is the practice of an adult educator truly liberatory if they let students develop the curriculum, lead class, or devise their own assessments? Marcuse would say no. For a course to be liberatory, adult educators need to provide experiences for students where they have the opportunity to have privacy and isolation. By being isolated and private, students are able to reflect on memory and become introspective (Marcuse, 1978). In a field that values collaborative learning and recognizes learning as a social process, this is a challenge. However, Marcuse states the isolation

experienced by students will trigger an experiential dissonance that helps them become aware of what life could be like (Marcuse, 1972). Once this dissonance appears, students will become politically aware and driven towards personal change. For Marcuse, social change originates with the liberation of the individual (Marcuse, 1972). In order for the liberatory process to occur, a distinct difference between educator and teacher is need. This is in contrast to the thought of many adult educators who have collaborative practices. Instead students need to participate in formally planned programs since "self-liberation is self-education but as such it presupposes education by others" (Marcuse, 1972, p. 47). Following this train of thought, Brookfield (2005) attempts to compromise with Marcuse and current adult education practices. He agrees that adult educators should plan experiences that allow for moments of isolation, but students should be able to navigate these moments with others.

Kamania Wynter-Hoyte et al. (2021) demonstrate why Marcuse calls for formally planned programs for learners. Through strategic planning, educators of elementary teacher candidates provide opportunities for students in their Urban Education Collective to learn "Black people cannot be human all by themselves" (Wynter-Hoyte et al., 2021, p. 271). For instance, teacher candidates were required to plan and teach lessons focused on topics ranging from multilingualism to African brilliance and languages. Part of the focus of these lessons was acknowledging African American Language (AAL) which challenged Eurocentric curriculum that leads speakers of AAL to experience deficit positioning (Wynter-Hoyte et al., 2021). By highlighting a new language and embracing it teacher candidates are challenging one-dimensional thought. However, Wynter-Hoyte et al. (2020) found in another study elementary teacher candidates struggled to break the Eurocratic stronghold in their own learning. Many students neglected to plan for the inclusion of AAL and left references to Africa out of their

lessons altogether. Teacher candidates also did not have confidence in communicating socially tough concepts, such as linguicism or prejudice against those who have a different native language. While teacher candidates were given their own experiences to explore and reflect on linguicism in their lives, they did not transfer this experience into their lessons. However, as teacher candidates learned and experienced more about the racialized nature of language positioning they began to understand their own liberatory journey through their formally planned program (Wynter-Hoyte, 2020).

Throughout a teacher candidate's time in an ITP program, a main form of learning is experiential. Practicum is when students are able to enact what they have been learning and developing in their own pedagogy. In order for this type of learning to lead to the liberatory process, students need to be able to deconstruct their experiences and identify the one-dimensional nature of them (Brookfield, 2005). It was difficult to find studies focusing on learning liberation for teacher candidates. I believe this is because learning to become a teacher is not often framed as liberating within the field of education, especially in science education. While the studies mentioned above focus on recognizing a new language (AAL) and incorporating it into education, they do not address the new language that teacher candidates encounter outside of jargon. My study not only focused on a population that has not been researched with from a liberatory perspective, but it also examined how teacher candidates utilize new language to engage in the liberatory process. Once teacher candidates are able to recognize and overcome oppression, they can begin to reclaim reason.

Reclaiming Reason

In order to use reason, an individual must "assess evidence, make predictions, judge arguments, recognize causality, and decide on actions where no clear choice is evident"

(Brookfield, 2005, p. 55). Brookfield (2005) selected Jürgen Habermas' work to ground the learning task of reclaiming reason. Habermas and Marcuse believe reason can be reclaimed to develop a humane democracy (Brookfield, 2005). Much of Habermas' writing focuses on how democracy and freedom are possible for society; yet, none of this can occur without reason. A prominent concept of Habermas' is the lifeworld. A clear definition of the lifeworld from Habermas (1987) is "the lifeworld forms the indirect context of what is said, discussed, addressed in a situation" (p. 131). Brookfield expands this definition by offering the lifeworld includes "all those assumptions that frame how we understand our experience of life and how we try to convey that experience to others" (p. 238). It is extremely difficult to identify the lifeworld in and of itself, but aspects of it, like assumptions, can be seen in moments when people need to respond to a situation with action (Brookfield, 2005). The lifeworld is constantly reforming and renewing itself as individuals engage in communicative action where the assumptions and ideologies individuals have are tested with reason. This could occur when individuals are asked to accept justifications, social arrangements, and suggestions as obvious fact (Habermas, 1996). It is here that adult education can support individuals of working to reshape their lifeworld with reason rather than pure assumption.

The adult learning task of reclaiming reason occurs when adults are able to apply reason to all aspects of their lives and decide what they value in them (Brookfield, 2005). Broadly, adult learners should participate in discourse and communicative action in order to question their assumptions, reclaim, and apply reason to their lives (Brookfield, 2005; Habermas, 1987). This learning task demonstrates how individuals come to decide what they value through recognizing their own assumptions and causality in their actions. In adult education, this looks like discussions, problem-based learning (Goodin et al., 2018; Peterson & Treagust, 1995), and

teaching scenarios (Schäfer & Seidel, 2015; Turkan & de Jong, 2018). Reasoning and noticing is used by adults to develop professional vision (Seidel & Stürmer, 2014). Professional vision is a set of "discursive practices used by members of a profession to shape events in the domain of professional scrutiny they focus their attention upon" (Goodwin, 1994, p. 606). Professional vision begins to develop while teacher candidates are in ITP programs, particularly during practicum (Weber et al., 2020). Andreas Gegenfurtner's (2020) team investigated the relationship between professional vision and reasoning of teacher candidates, in-service teachers, and school principals. They found that teacher candidates noticed and used reasoning, focused in pedagogy, less than principals and in-service teachers. This finding is not surprising since teacher candidates are at the start of their careers. Their results did suggest teacher candidates struggled with metacognition and recognizing their own thinking patterns which aligns with their findings. Other research teams have examined how teacher candidates use and grow in their reasoning skills through their ITP program.

The primary usage of reasoning in many ITP programs is pedagogical reasoning. The concept of pedagogical reasoning is not new and was first proposed by Lee Shulman in 1987. John Loughran (2019) defines pedagogical reasoning as "the thinking that underpins informed professional practice" (p. 526). Pedagogical reasoning illustrates why teachers make the decisions they do in the classroom and what they are valuing in their practice (Loughran, 2019). Ray Peterson and David Treagust (1995) designed a course for primary teacher candidates focused on teaching science that highlighted methods for developing pedagogical reasoning. Peterson and Treagust (1995) found participants began developing and using pedagogical reasoning in their thinking. A significant finding was the importance of giving teacher candidates the opportunity to place themselves in the position of others. Terry Goodin et al. (2018) studied

how an ITP program based on a combination of the medical school model of practice-based learning and problem-based learning (PBL) encouraged teacher candidates to develop pedagogical reasoning. Teacher candidates participated in small group work, professional learning communities, and roles within PBL groups. Their findings revealed participants were better at reflecting and using their metacognition to explain their reasoning for decisions in their practicum experience. Another approach to developing teacher candidates' ability to reason is using scenarios or noticing tasks. Stefanie Schäfer & Tina Seidel (2015) had teacher candidates half-way through their ITP program view a video of a physics classroom dominated by teacher-centered activities. They were asked to write down what they noticed. The researchers then analyzed the teacher candidates' responses. Schäfer & Seidel (2015) found teacher candidates were already using professional vision to reason; however, they still struggled to completely engage their professional knowledge for pedagogical reasoning. The above studies show the importance of how ITP programs are designed to support teacher candidates in developing their pedagogical reasoning skills.

Much of the focus of the literature towards adult learners reclaiming reason attempts to discern when and how learners begin to develop their reasoning skills. In teacher education programs, there has been research done to determine which instructional strategies support teacher candidates in honing their pedagogical reasoning. After looking over the literature, I could not help but notice many of the studies are classroom focused and not broader social issues that influence the classroom. The literature also highlights specific interventions taken in ITP program courses to elevate reasoning. It ignores the personal factors teacher candidates bring with them to their ITP programs that may influence their ability to reason. This study did not look at specific interventions, but instead evaluated how the contextual and personal factors

influences science teacher candidates' ability to reclaim reason. The study also followed science teacher candidates through their whole program instead of one semester or course.

Learning Democracy

For this learning task, Brookfield (2005) looks to two adult learning theorists: Eduard Lindeman and Jürgen Habermas. Lindeman's work focused on understanding the role democracy had in adult education. While Lindeman is often associated with pragmatism and not critical theory, Brookfield (2005) draws on his work due to Lindeman's analysis of how democracy influences adult education. For this study, I selected to use Brookfield's (2005) definition of democracy based off Lindeman's work. Democracy is when adults can "deal respectfully with difference, live with unresolved conflict, and accept that proposed solutions to complex social problems should always be viewed as temporary, as contingent" (Brookfield, 2005, p. 61). Habermas, a critical theorist, also focused his work on democracy, specifically in discourse theory. Brookfield (2005) merged their work together to develop the critical adult learning task of learning democracy. A key assumption made when discussing learning democracy is adults are continuously learning. Brookfield (2005) drew upon Habermas' (1975) thoughts about the type of learning adults' experience. The main types are nonreflexive and reflexive learning. Nonreflexive learning is not critical and occurs when an adult learns to not resist the dominate culture (Habermas, 1975). Reflexive learning is critical. This type of learning happens when adults question and challenge the status quo through communicating with others who have different perspectives (Habermas, 1975). An aspect of reflexive learning is evolutionary learning. This type of learning must take place in order for an adult to learn democracy. Evolutionary learning brings about shifts and changes in how individuals function within systems that leads to societal development (Habermas, 1975). Two conditions must

happen for evolutionary learning to take place: (1) there must be an unresolved systemic issue present and (2) an individual has learned about the systemic issue but not had the opportunity to take action in the system (Habermas, 1975).

The ways adults participate in learning democracy within formal educational settings is varied. Students may work together to form norms in the classroom, negotiate activities, participate in discussions with others who have different points of view, and engage in critical reflection. This activity is rooted in the development of moral consciousness as outlined by Habermas (1990). The level at which moral consciousness comes into being depends on an adult's ability to detach themselves from their normal way of thinking and act in a way that is not predetermined by their current ideologies. This happens when an adult is "aware of life's contingencies, by her recognizing the contextuality of beliefs, and by the ability to understand that thought is ideologically shaped" (Brookfield, 2005, p. 257). Awareness, recognition, and understanding form through communicating with others who have different experiences of the world. Ken Zeichner and team (2014) explored what this may look like in teacher education in their study. The study focused on two ITP programs that networked with community-based educators and parents to incorporate different perspectives in education. They found fostering these relationships in hybrid settings lessened the power dynamics (university v. community leaders) in relationships. Similarly, Kristin Cipollone and colleagues (2022) researched how community-engaged teacher preparation supported teacher candidates in incorporating culturally responsive teaching into their practice. Teacher candidates in the ITP program were matched with a community mentor or mentor family for a semester. They "participate with and alongside residents in programs and projects integral to community revitalization identified by members of the neighborhood" (Cipollone et al., 2022, p. 74). Teacher candidates reflected on their

experiences and the “courageous conversations” held between them, the community members, and the teacher educators in the ITP program. The involvement of members of the communities where ITP programs are placed is not the only focus of democracy based education research.

Many ITP programs look to other stakeholders to encourage teacher candidates to align with democratic practices in the classroom. Katherina A. Payne (2018) examined how teacher candidates developed moral consciousness in the classroom when working with a mentor teacher who enacted democratic practices. Payne (2018) found student teachers felt like knowledge holders in the classrooms with their mentor teachers due to their mentor teachers’ ability to employ moral consciousness. Because of this, teacher candidates had moral consciousness modeled for them while in the classroom. This framing brought about evolutionary learning for several participants. For instance, Diego, a teacher candidate, and his mentor teacher, Maya, considered the “achievement gap” for their district, which led to them incorporating culturally relevant pedagogy into the classroom together. In Diane L. Duffin and team’s (2018) study, teacher candidates took two courses in the same semester: (1) Teaching in a Democratic Society and (2) Introduction to American Politics. Students worked in groups of four to five to develop a final presentation on a contemporary issue in education in the last month of the semester. A mentor from the political science or education department was assigned to assist the group. Students took an eight-question survey before and after the project that measured their democratic dispositions. Duffin et al. (2018) found students demonstrated significant growth in all but one response, particularly the statement “People who disagree with me usually have good reasons for feeling the way they do.”

The above studies demonstrate the importance of offering opportunities for teacher candidates to grow and learn from others in order to embrace democratic practices in the classroom. When teacher candidates are presented with and begin to experience the different critical learning tasks, they do so through their personal factors.

Teacher Candidates' Personal Factors

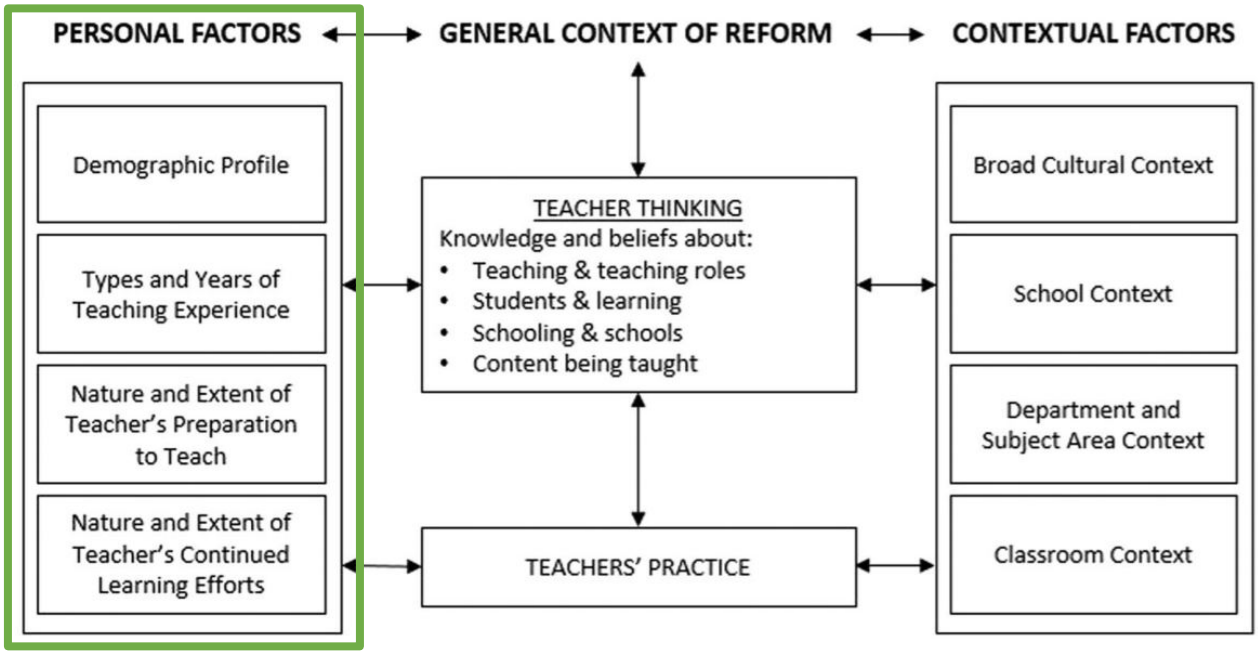
The Teacher-Centered Systemic Reform (TCSR) model (Figure 2.1) was originally designed for in-service teachers, but has been used in other contexts, such as with university faculty (Woodbury & Gess-Newsome, 2002). While the majority of the model still applies to teacher candidates and their experiences, certain areas under personal factors simply do not work. For instance, the "nature and extent of teacher's continued learning efforts" cannot apply to teacher candidates since they have not had enough time in the field to extend their learning. I have also chosen to alter the interpretation of "types and years of teaching experience" to better suit teacher candidates. For this study, participants did have informal teaching experience which was considered, but only one had formal teaching experiences prior to the ITP program. The types of teaching experiences teacher candidates have while in the ITP program are influenced by their mentor teacher and attempts to implement social justice into their teaching. Because of this, I have chosen to incorporate these elements into "types of teaching experience."

The positionality of an individual influences how they interact with the world (Harré & Van Langenhove, 1999). The aspect of "demographic profile" helps support the examination of how teacher candidates either align with or resist critical science education ideologies. This section not only offers a chance to understand how and why teacher candidates participate in the critical learning tasks, but their own perceptions of the other elements in the TCSR model. Age, race, gender, class, ethnicity, and other subjective aspects were taken into consideration as

personal factors. In this section, I explore what the literature has to say about personal factors of teacher candidates, specifically in demographics and teaching experiences. Then, I will discuss how this study fit within the literature around teacher candidates' personal factors.

Figure 2.1

Personal Factors in the Teacher-Centered Systemic Model



Modified from Woodbury & Gess-Newsome, 2002

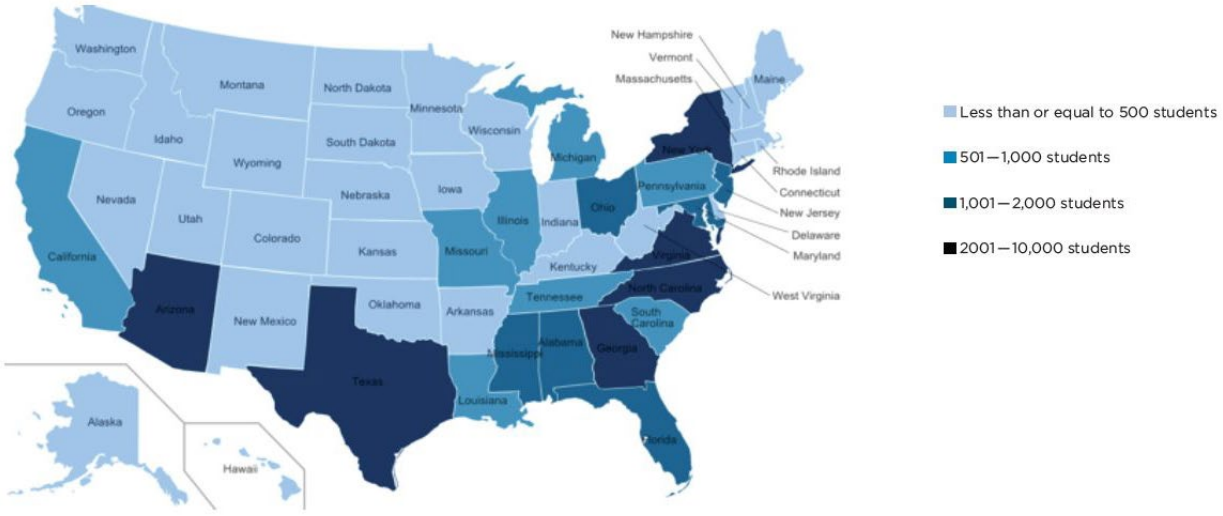
Demographic Profile

The teaching force is composed of 79 percent of teachers who identify as White (U.S. Department of Education, 2017). However, White teachers make up 75 percent of first-year teachers in the 2015-16 school year (Carver-Thomas, 2018). While this is still a large percentage, it has decreased since 1987 when White teachers made up 90 percent of first-year teachers (Carver-Thomas, 2018). In teacher preparation programs, 74 percent of teacher candidates are White with nine percent identifying as Black, 10 percent Hispanic, and only two percent Asian (U.S. Department of Education, 2016). Within science, 91 percent of high school,

as well as middle school teachers are White with six and seven percent identifying as Hispanic or Latino (Banilower et al., 2018). Black teachers compose five percent of high school science teachers and eight percent of middle school science teachers. While Asian middle school teachers are two percent of the science teacher workforce and five percent of high school teachers (Banilower et al., 2018). Science teachers younger than 30 make up 14 percent of high school science teachers and 17 percent of middle school teachers with the largest age group being 31-40 years old. Following the trend of all teachers, 57 percent of high school science teachers are female, but 71 percent of middle school science teachers are female (Banilower et al., 2018). Based on this research, the dominate group within science educators are White women between the ages of 31-40. The trend of White women being dominate in education is mimicked in ITP programs throughout most of the United States (Figures 2.2 and 2.3). What causes this trend to persists?

Figure 2.2

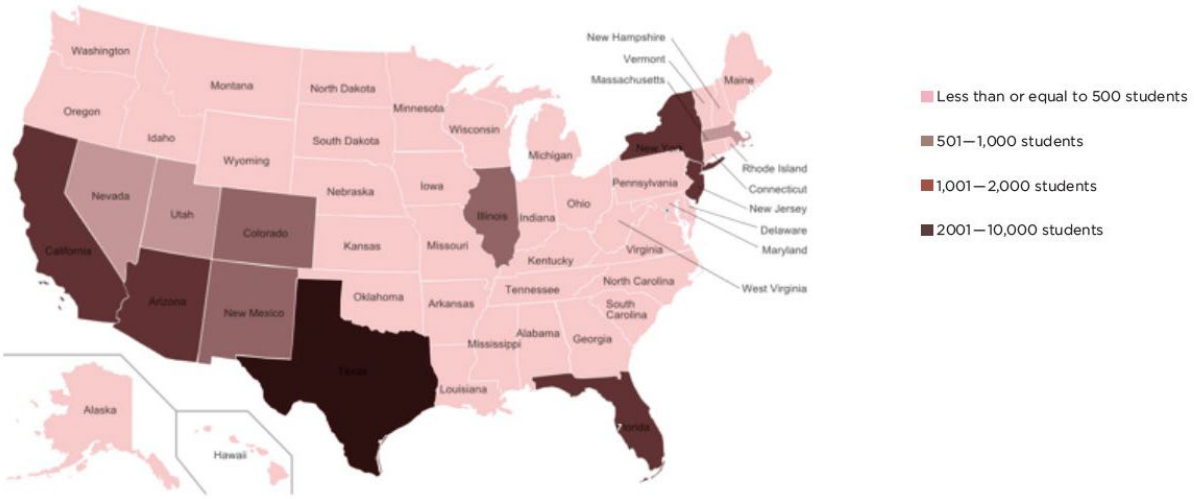
2013-14 Enrollment of Black Teacher Candidates in an ITP Program



Source: U.S. Department of Education, Office of Postsecondary Education, 2015

Figure 2.3

2013-14 Enrollment of Hispanic Teacher Candidates in an ITP Program



Source: U.S. Department of Education, Office of Postsecondary Education, 2015

In order to answer this question, I must start at the beginning of the journey to becoming a teacher: The K-12 classroom. Students of color are more likely to be suspended from school, not graduate high school, and experience achievement debt (Carver-Thomas, 2018; Ladson-Billings, 2006). Students of color are less likely to graduate college within six years (U.S. Department of Education, 2017). Reasons students of color may struggle to complete their degree range from being underprepared for college-level course work to difficulties being in an environment that does not reflect or respect their culture/experience (Carver-Thomas, 2018). Another barrier to completing college comes in the form of financial strain. Black, Latinx, and Asian American students are more likely to have student loans limit their choice in colleges than White students (Baum & O'Malley, 2003).

While these barriers persist, the number of teachers of color continues to not represent the student population (U.S. Department of Education, 2017). To understand what drives individuals of color to become teachers, researchers have asked what their motivation is.

Tara Plachowski (2019) examined how K-12 education experiences influenced teacher candidates of color to become educators. Her findings showed teacher candidates who felt like they mattered and were recognized by their teachers wanted to replicate those experiences for their students. Even participants who had negative experiences as students wanted to be the resource and advocate they did not have. In science education, Samantha Strachan (2020) worked with two Black male teacher candidates to understand why they chose to become science teachers. Each participant spoke about their love of science and teaching, but also wanting to be an example for their students in science and life. Christine McDonald (2017) explored factors that influenced science teacher candidates to become teachers. Through working with 12 science teacher candidates, she found their experiences while in high school influenced their decision to follow science as a career. In particular, implicit and explicit messages from teachers and parents about the status of teachers caused participants to seek another career before entering an ITP program. Many of them ultimately chose to enter the field of science education due to being unhappy in STEM jobs. Each of these studies demonstrates how intrinsic and altruistic motivation from teacher candidates leads them to choose the profession of education.

While my study did not seek to examine why individuals choose to become science teacher candidates, it did have participants from various demographic backgrounds. Understanding their motivation and the barriers they overcame to enter a science ITP program helped with recognizing what ideologies science teacher candidates bring with them. These experiences in K-12, college, and outside of undergraduate work supported what teacher

candidates value and seek for themselves as future science teachers. How my participants viewed themselves as teachers working with specific student populations informed how they either align with or resist the ideology they encountered in the ITP program.

Nature and Extent of Teachers' Preparation to Teach

The term "alternative" has been used throughout the literature to describe a non-traditional route to becoming an educator. This begs the question, "What is the traditional route to be a teacher?" Graduates of traditional teacher programs complete a four-year degree in education, have had a long-term interest in becoming a teacher, and are typically young, White middle-class females (Guyton et al., 1991). Whereas, individuals who participate in alternative teacher preparation programs are generally career changers, older, and more racially or ethnically diverse (Koballa et al., 2005). Alternative teacher preparation programs were developed in response to a significant shortage of qualified teachers in high needs areas like science (U.S. Department of Education, 2002). These programs were designed to produce qualified teachers within a single academic year to enter the work force at an accelerated rate. Individuals who qualify for the programs are required to have a bachelor's degree in the intended area of instruction and meet other acceptance criteria of the selected university and/or college (Guyton et al., 1991; Koballa, et al., 2005; Marco-Bujosa et al., 2019). Alternative teacher preparation programs were first established in 1982 (Lederman et al., 2006a). Since then many studies have been conducted to analyze the variety of differences found between alternative and traditional teacher preparation programs.

Teacher candidates who enter these programs have different experiences in life to draw upon during their training, and this impacts their views about science education as opposed to candidates found in traditional teacher preparation programs (Koballa et al., 2005). One of the

first studies to compare teachers from alternative and traditional preparation programs was conducted by Darling-Hammond (1990) in the form of a review. She concluded all routes of teacher preparation should be evaluated based on the quality of student teaching experiences given to support pedagogical and content knowledge. Guyton, Fox, and Sisk (1991) followed shortly after and compared the performance of teachers prepared by alternative or traditional preparation program in Georgia. The findings revealed there was not a significant difference in the teaching performance between the alternatively and traditionally prepared teachers in the first year of teaching. A follow-up study was conducted by Jelmberg (1996) focusing on New Hampshire teachers. Jelmberg's study found a difference in motivation for entering education, as well as feelings of preparedness to enter the classroom. More recently, Whitford, Zhang, and Katsiyannis (2018) found a small, but significant effect indicating students who had teachers from alternative preparation programs achieved more that those students with traditionally prepared teachers.

Early Research Literature

The early research comparing teachers from alternative and traditional teacher preparation programs found few differences in effectiveness (Darling-Hammond, 1990; Guyton et al., 1991). One noticeably different study was Jelmberg (1996) who found significant differences between alternative and traditionally prepared teachers, favoring traditionally prepared. However, it should be noted 30 alternative teachers were compared with 200 traditionally prepared teachers. This can dramatically skew the quantitative results presented. Darling-Hammond (1990) found four characteristics of both types of preparation programs: (1) when adequate preservice education is combined with on-the-job intensive supervision, satisfaction is higher, (2) well-supervised, high-quality, and rigorous student teaching

experiences were significantly related to teacher effectiveness, (3) subject knowledge is effective, but does not make up for lack of pedagogical knowledge, and (4) relationships between education courses and teacher performance were strong. Meanwhile, Guyton, Fox, and Sisk (1991) analyzed teachers prepared through both types of programs. They focused on the teachers' performance, attitudes, and efficacy. One of the only differences found was in the induction support offered with traditionally prepared teachers reporting they were supported emotionally and professionally while alternative teachers did not.

The literature found comparing alternative and traditional teacher preparation programs were conducted quantitatively. Because of this, the voice of the teachers is missing. While it is reported alternatively prepared teachers have different motivations for entering education than traditionally prepared, no direct quotes or personalized data is presented (Guyton et al., 1991; Jelmberg, 1996). Both Guyton, Fox, and Sisk (1991) and Jelmberg (1996) included former provisional teachers in their studies as graduates of alternative teacher preparation programs. However, the focus of these studies was on the quality of teachers produced, not the differences of types of individuals found in these programs or their experiences while in the program.

Current Program Comparison Literature

The current research has supported findings from Guyton, Fox, and Sisk (1991) and Darling-Hammond (1990) that there is little difference between the effectiveness of teachers prepared traditionally or alternatively. Whitford, Zhang, and Katsiyannis (2018) determined a small, but statistically significant effect indicating the mean achievement of students who had alternatively prepared teachers had a standard deviation above students who had traditionally prepared teachers in middle school. In high school, they did not find a statistically significant result for total academic achievement. This further supports the idea there is little difference

between alternative and traditionally prepared teachers in their classrooms. In their study, Koballa et al. (2005) had three participants from an alternative teacher program in Georgia. The participants ages were 23, 41, and 48 years old. The average age of participants in traditional teacher preparation programs is early 20s (Koballa et al., 2005). Teacher candidates in alternative teacher programs tend to be "older, more ethnically diverse, and more experienced in the private work sector" (Koballa et al., 2005, p. 288). Lederman, Lederman, and Abd-El-Khalick (2006a) believe the largest difference between alternatively and traditionally prepared teachers is "alternative certification teachers are more committed to teaching, more willing to work in disadvantage areas, more willing to work with lower-ability students, and more diverse in terms of ethnicity" (p. 267). Findings presented by Carver-Thomas and Darling-Hammond (2019) support this claim. Carver-Thomas and Darling-Hammond (2019) found teachers from alternative teacher preparation programs are more likely to work in Title I schools, move schools more often, and are more likely to teach students of color.

Little has changed in the 20 plus years since research began comparing alternative and traditional teacher preparation programs. Not only have the findings continued to support that there is little difference in teacher effectiveness, many of the studies are still conducted through quantitative means. While this is not a negative finding, it still does not reveal the participants' voices, thoughts, or experiences. Carver-Thomas and Darling-Hammond (2019) look at critical aspects of teaching, such as race, gender, and socioeconomic status. However, Whitford et al. (2018) and Koballa et al. (2005) do not focus on critical factors and their influences in their findings. Regardless of the type of ITP program teacher candidates participate in, their teaching experiences while influence their thinking, beliefs, and practices around science education.

Teaching Experiences

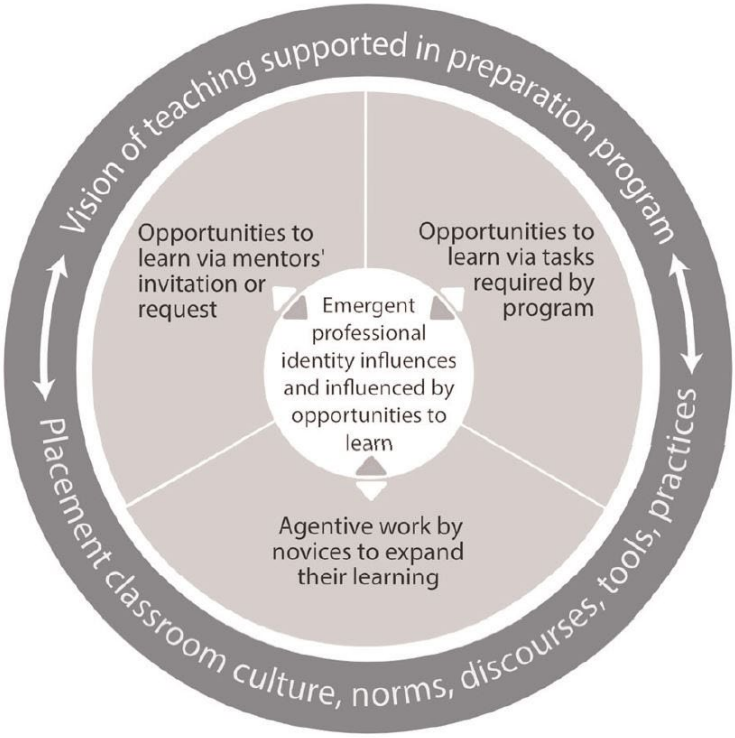
I have heard ITP programs described as learning how to ride a bike. The coursework can teach students about the theory of how a bike works, the benefits of riding a bike, how to build a bike, and the role of particular pieces that contribute to the bicycle working well. However, practicum, or student teaching, is where an individual learns how to actually ride a bike. No one else can do it for them. Teacher candidates must have the opportunity to apply their growing understanding of teaching. Here, they work towards removing the training wheels and selecting which kind of bicycle works best for them. In a literature review conducted by Ester Cohen, Ron Hoz, and Haya Kaplan (2009) about practicum, they found the rationale for the practice to be 1) teacher candidates' applying their knowledge of pedagogy, 2) to reduce the gap between practice and theory, 3) to become more comfortable with being in a school setting as an authority figure, and 4) to develop their identities as a teacher. Melissa Braaten (2019) observed, interviewed, and used artifacts from 22 science teacher candidates to better understand how they utilized their pedagogical training in the practicum experience. She observed a variety of delivery pedagogies being used by science teacher candidates from Initiate-Response-Evaluate (IRE) to eliciting student ideas. Many of the science teacher candidates worked towards breaking away from the IRE model of discourse and attempted to recontextualize eliciting ideas from students. This most often occurred in small-group interactions indicating science teacher candidates view interactions within small groups as essential for meaningful science learning. Yet, in order for these opportunities to explore pedagogical moves teacher candidates need to be able to take the lead in their placement course.

Mark Windschitl et al. (2021) confirmed what many teachers who have experienced practicum know: not every teacher candidate has the same opportunity to practice teaching. In

their study, Windschitl et al. (2021) found 60 percent of their 65 participants were placed in classrooms where the pedagogy reflected teacher-centered and non-reformed science teaching practices. The science teacher candidates in the placements described above did not get a chance to lead classes on average until February, six months into their practicum experience. Science teacher candidates often relied on their practicum course assignments to provide opportunities to practice the pedagogical theory they experienced from their ITP program. The complexities of the practicum experience and why it is so personal can be seen in figure 2.4. From this model, the role of the mentor teacher and their allowance of teacher candidates to instruct in their classroom has major impacts on the professional identity that emerges for the teacher candidate.

Figure 2.4

Learning Interactions Experienced by Teacher Candidates in Practicum



Source: Windschitl et al., 2021

Mentor Teachers

The relationship between a teacher candidate and their mentor teacher is important. Teacher candidates begin to form their teacher identity during practicum (Cattley, 2007). While major shifts in their teacher identity are not often seen in practicum (Borko & Mayfield, 1995; Kelchterrmans, 1993) Masha Izadinia's (2015) found the relationship between mentor teachers and teacher candidates impacts the confidence of teacher candidates in the classroom. Confidence is a component of teacher candidates' teacher identity (Izadinia, 2013). Teacher candidates who lack a rapport and personal connection with their mentor teachers are less likely to reflect on their practice and accept new pedagogical challenges, such as trying a new instructional strategy (Izadinia, 2015). In contrast those who have positive experiences with their mentor teacher, often feel like teachers at the end of their practicum by having a sense of authority in the classroom (Izadinia, 2015).

Different studies have found mentor teachers have the ability to positively influence teacher candidates' teaching practices, content knowledge, and pedagogical knowledge (Matsko et al., 2018; Ronfeldt et al., 2018). However, Kayla Norville and Soonhye Park (2021) found mentor teachers did not seem to have an overall impact of science teacher candidates pedagogical content knowledge (PCK). A potential challenge to the development of science teacher candidates' development of PCK was seen in the need to negotiate the power dynamics between themselves and their mentor teacher (Norville & Park, 2021). In a study completed by Rachel Patrick (2013), she examined how mentor teachers and teacher candidates worked together. She found that "in mentoring relationships assimilation into the profession was favored above collaboration about learning and teaching" (p. 222). Because of this, it is important mentor teachers continue their learning through professional development.

Maris Thompson and Alfred Schademan (2019) conducted a study over four years with mentor teachers and teacher candidates. They sought to understand the key practices to a successful mentor and teacher candidate relationship, as well as how each supported the other in professional development. Thompson and Schademan (2019) found five primary practices that occur daily between mentor teachers and teacher candidates: 1) negotiating difference, 2) sharing authority, 3) co-mentoring, 4) coaching in the moment, and 5) deep immersion in real world teaching. When each of these practices were enacted in classrooms, both the mentor teacher and teacher candidate grew in their understanding of how to meet students' needs (Thompson & Schademan, 2019). Yet, they recommend ITP programs offer professional development for mentor teachers to support them in learning new pedagogies.

David Stroupe and James B. Hancock II (2022) worked with science mentor teachers to aid in their understanding of the Next Generation Science Standards (NGSS) and Ambitious Science Teaching (AST) practices. Following four mentor teachers through a year-long professional development while mentoring, Stroupe and Hancock (2022) found how the mentor teacher views their role in the practicum process impacted their willingness to engage with NGSS and AST practices. Two mentor teachers treated their science teacher candidates as partners in the classroom. They often sought help from their science teacher candidate in practices, such as planning and reflection. While the other two mentors viewed their role as guiding the science teacher candidates into "real teaching" (Stroupe & Hancock, 2022, p. 7). Consequently, one of these mentors quit the program altogether, and the other blamed NGSS and AST practices for his science teacher candidate's classroom facilitation issues. While this article does not explore the impact on science teacher candidates, it demonstrates the importance of the mentor teachers' own positioning in the classroom. Ultimately, the level of comfort and

willingness to give away some control on the mentor teacher's part, dictates what teacher candidates are able to practice in their practicum. This is seen often when teacher candidates attempt to implement social justice pedagogies.

Implementing Critical Pedagogies in Teaching

With the focus of science standards shifting towards NGSS, science teachers are expected to teach science to all students (See Chapter 1). Many studies have been conducted to understand how science teachers can do this through their practice (Moore, 2013; Philip & Azevedo, 2017; Szoztkowski & Upadhyay, 2019). Yet, when Vicky Duckworth and Bronwen Maxwell (2015) conducted a literature review of social justice in relation to mentoring, they found social justice is marginalized by in the practicum experience due to the instruments used for assessment of teacher candidates. Mentor teachers focused more on content instructional practices than incorporation of social justice. In spaces where teacher candidates had mentor teachers comfortable with social justice topics, they were encouraged to reflect critically, implement critical pedagogies, and felt supported in their attempts to incorporate critical topics. The interventions of mentor teachers have the ability to support teacher candidates in addressing topics the often feel are uncomfortable in the classroom (Gardiner, 2011; Yendol-Hoppey et al., 2009).

As stated above, the dominate group teaching in science and overall, are White women. It has been shown that science teachers tend to teach from their own worldview and culture rather than incorporating culturally sustaining or culturally relevant pedagogies (Gay, 2018). Social justice teaching can be encapsulated within critical pedagogy (Moore, 2008a). Teachers who use critical pedagogy seek to help students develop their identities, utilize community resources, and work to co-construct knowledge and action with students (Arellano et al., 2016; Calabrese

Barton & Osborne, 2001). Teacher candidates encounter an ideology that asks them to question how their instruction and curriculum helps students understand themselves, others, power, equity, and anti-oppression (Muhammad, 2020). A way they can do this is to consider the ways lessons address the identity, intellect, skills, criticality, and joy of their students (Muhammad, 2020). Teacher candidates usually encounter critical pedagogy in multicultural courses during their teacher preparation (Moore, 2008b). Even so, critical science pedagogy is not traditionally found in a secondary science classroom (Arellano et al., 2016). In order to better understand why this is not a focus in science classrooms, researchers have begun to look to science preservice teachers' views on criticality.

Seema Rivera and Preethi Titu (2021) conducted a study reviewing science teacher candidates' discussion posts around three articles focuses on diversity and equity. Their participants are all White and expressed similar views. The teacher candidates acknowledged the differences between themselves and their students in culture. However, they were uncomfortable discussing or even acknowledging race with their students. Each teacher candidate stated they do not see color when they look at their students and struggled to find a connection between science and race. Yet, the one teacher candidate who did talk about race, Eric, was not uncomfortable because he claimed racism does not exist (Rivera & Titu, 2021). However, Carmen Mills (2013) followed two teacher candidates through the final two years of their ITP program. She found each participant shifted in their understanding of providing equitable education to their students. From wanting to treat every student the same to realizing every student is unique occurred because the teacher candidates were able reflect on their practice and their students.

Mills (2013) makes sure to point out each teacher candidate experienced a shift in their views around critical pedagogy at the same time in their program: the end of their first year. Mills (2013) attributes this shift to the development of their teacher identities due to having been in the classroom.

Summary

I remember when I first starting reading empirical research articles in science education the participants were always teacher candidates. Naïvely, I thought, "Don't we know enough about these students?" Now, I know better. Science teacher candidates are individuals who have chosen to enter a field where they are learning reformed ways to teach science. Yet, researchers know they do not often carry the ideologies and practices presented to them in their ITP program into their own classrooms as beginning teachers (Koballa et al., 2005). By seeking to examine how personal factors influence science teacher candidates' alignment or resistance to critical science education pedagogies, this study holistically analyzed teaching experiences with mentor teachers and critical pedagogies. Personal factors work together to inform how teacher candidates think about different aspects of education.

Teacher Candidates' Thinking

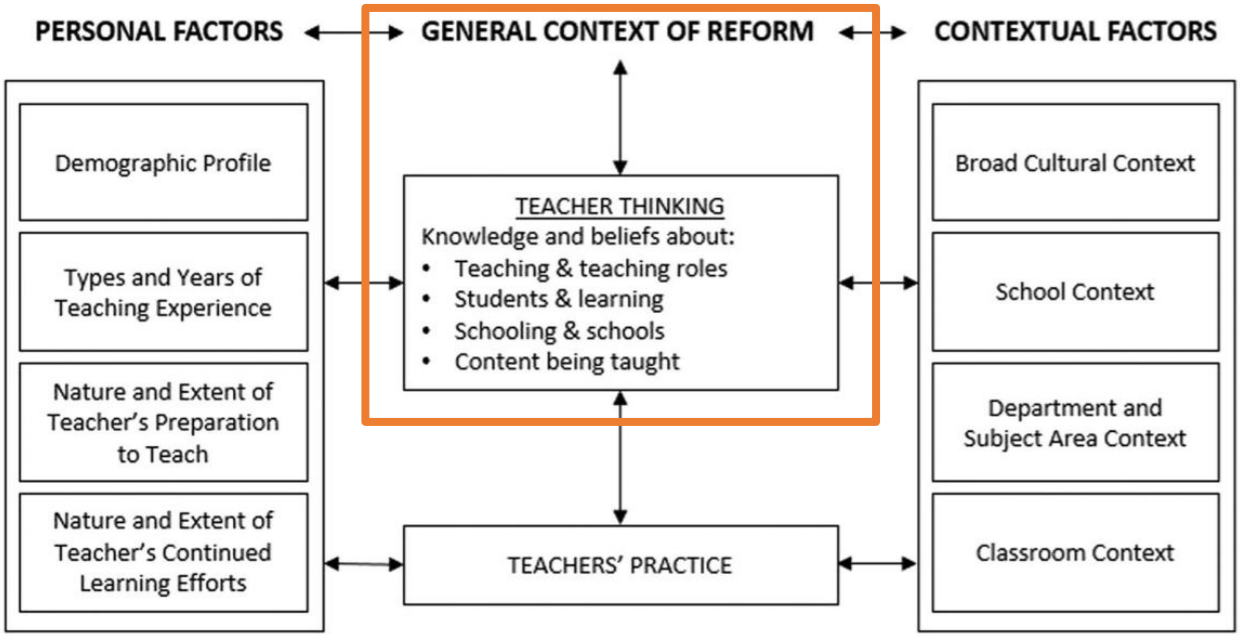
While I was a classroom teacher, I participated in and led many professional developments. In my last two years working for a district, I introduced and supported science teachers in working on implementing new state standards into their classrooms. In order to fully teach the new standards, science teachers needed to shift their thinking about how science is taught. The amount of pushback I encountered from teachers was new to me. When I started to work with science teacher candidates, I began to encounter pushback about instructional strategies that, at the root, were related to teacher candidates thinking around several factors:

critical pedagogies, the teacher's role, student learning, and the subject of science. Having run into this before, I was unsurprised to read in Woodbury and Gess-Newsome (2002) that teacher thinking is the lynchpin for the success or failure of education reform.

Teacher thinking encapsulates beliefs and knowledge (Woodbury & Gess-Newsome, 2002). Beliefs and knowledge are intertwined and often are difficult to disentangle from each other, and are powerful, self-perpetuating factors that are at the heart of a teacher or teacher candidate's decision making (Pajares, 1992). Because of this, teacher thinking is placed in the core of the teacher-centered systemic reform (TCSR) model (Woodbury & Gess-Newsome, 2002). In figure 2.5, the components that make up teacher thinking are shown. For this study, I chose to incorporate schooling and schools into the contextual factors as part of school culture. This is because school culture often impacts and can be a representation of group thought about the role of and how schools should function (Deal & Peterson, 1991; Peterson, 2002). I focused on science teacher thinking around critical pedagogies, the teacher's role, students and learning, and the subject of science. In this section, I will explore each area of thinking for teacher candidates and then explain how this study was situated in the literature.

Figure 2.5

Teacher Thinking in the Teacher-Centered Systemic Model



Modified from Woodbury & Gess-Newsome, 2002

Critical Pedagogies

"A social justice stance requires a systemic approach that includes fair and equitable teaching practices, high expectations for all students, access to rich, rigorous, and relevant [science], and strong family/community relationships to promote positive [science] learning and achievement."

Males et al., 2020

Recent studies found over 50 percent of the student population in the United States identify as students of color (African American/Black, Native American, Latin American, Caribbean, Asian/Pacific Islander descent and two or more races; U.S. Department of Education, 2017). Yet, these findings are not reflected in the teaching force where 79 percent of teachers identify as White (U.S. Department of Education, 2017). Because of this, "teachers need to develop culturally relevant teaching practices that use [critical pedagogy] principles to

interrogate the social, economic, political, and ideological contexts of schooling and to act upon their power as change agents who can transform the world" (Ajayi, 2017, p. 52). However, the predispositions of teacher candidates are a more powerful socializing influence than their ITP program (Lortie, 1975). The predispositions of teacher candidates are grounded in ideologies that include biases and assumptions about the aspects of critical pedagogy mentioned in the quote from Males et al. (2020). Particularly in science education, teacher candidates hold hegemonic assumptions about teaching diverse students science (Moore, 2009). The types of assumptions science teacher candidates hold about diverse students are around language, appropriateness of curriculum, and their ability to achieve (Moore, 2009). If these assumptions and biases are not addressed in an ITP program, then teacher candidates will not employ critical pedagogies or tend to the needs of diverse learners (Moore, 2008b; Nieto, 2000; Rodriguez, 1998).

In a review of literature focused on teacher candidate preparation, A. Lin Goodwin and Kelsey Darity (2019) found only four percent (76) of 1796 articles pertained to preparing teachers to implement social justice into their classrooms. Sixty-nine percent of the 76 articles focused on understanding the beliefs of teacher candidates about social justice. For many of these articles, teacher candidates experienced an intervention in their ITP program that caused them to become more aware of their biases, reduce deficit thinking, and have greater cultural understanding (Goodwin & Darity, 2019). However, only two articles focused on pedagogical knowledge where authors describe instructional strategies used to engage teacher candidates' beliefs or expose them to other contexts. An article that does provide a pedagogical strategy used with science elementary teacher candidates focuses on the use of book clubs. Felicia Mensah Moore's (2009) teacher candidates read the ethnography Ways with words: Language, life, and work in communities and classrooms by Shirley Brice Heath (1983). Students were placed in

groups and discussed parts of the book with their groups in class using open-ended questions provided by Moore. At the end of class, students were given the opportunity to share from their small group with the whole class. After the third book club meeting, all of the groups' notes from their discussions were posted for the whole class to see. Students were asked to write an individual reflection, along with a group reflection paper. The groups then presented what they learned in their book club to the class. Moore (2009) found five themes in how the book club revealed changes in science teacher candidates thinking: 1) relevancy – using a multicultural text in a science methods course, 2) revelation – revealing assumptions and biases about issues of diversity and teaching science, 3) responsiveness – forcing a response to issues of diversity in science education, 4) reflection – developing critical and reflective science teachers, and 5) reformation – gaining a deeper understanding of diversity by changing ideological beliefs. Initially, Moore's (2009) students viewed multiculturalism and issues of diversity as irrelevant to science and their teacher preparation, but after the book club they viewed these issues as highly relevant to their preparation as science teachers. Even so, teacher candidates, specifically White teacher candidates often resist critical pedagogy, social justice, and multicultural education (Han 2013, 2014; Hatch & Groenke 2009; Marx 2006).

To further explore these findings, Keonghee Tao Han, Marga Madhuri, and W. Reed Scull (2015) conducted a study comparing teacher candidates' acceptance or resistance of critical pedagogy in two elementary literacy methods course. One group of students was located in a rural, homogenous location and the second group was in an urban, diverse area. Students in both contexts were engaged in similar experiences with the same instructional strategies, including book clubs. Han et al. (2015) found students in the rural ITP program actively resisted critical pedagogy. Three themes emerged with the rural group of all White teacher candidates: 1) teacher

candidates' lack of exposure to diverse students and families, 2) a sense of White superiority over others, and 3) resistance to multicultural and social justice education. While the more diverse teacher candidates in the urban ITP program came to be more accepting of critical pedagogy, they still displayed only a surface willingness to accept social justice curriculum. Han et al.'s (2015) findings demonstrate how teacher candidates' exposure and relation to diverse communities prior to and during ITP programs impact their willingness to understand the need for and implementation of critical pedagogy in the classroom. Lasisi Ajayi (2017) also conducted a study with teacher candidates in a rural environment; however, 13 of her 14 participants identified as Mexican American. Unlike Han et al. (2015), Ajayi found her students were open to engaging in critical pedagogy but struggled to implement it in the classroom. The teacher candidates reported specific contextual factors, such as less resources, school culture, and curriculum, limited their ability to enact critical pedagogy. While Ruchi Bhatnagar et al. (2016) found that teacher candidates in an urban teacher education program felt their ITP program prepared them well for respecting diverse beliefs and cultures. Yet, students stated they felt unprepared to critically analyze education policies and practices. Being able to have systemic approach to teaching and having a critical eye of the system is an integral aspect of utilizing critical pedagogy (Arellano et al., 2016). This reiterates the findings from Han et al. (2015) where urban teacher candidates are willing to accept critical pedagogy, but this is often a sallow understanding.

When reflecting on teacher candidates thinking around critical pedagogy, I am reminded of the adage "Actions speak louder than words." The studies presented here demonstrate that even when teacher candidates are willing to align their thinking to critical pedagogies, they struggle to implement them in the classroom. What role does teacher candidate thinking have in

continuing this identified barrier in the literature? By addressing this question through a holistic approach, this study aimed to better understand what perpetuates extreme and lukewarm reactions to critical pedagogy from teacher candidates. Before teacher candidates think about enacting critical pedagogies, they may question what their role in the classroom as a teacher looks like.

Teacher's Role, Learning, & Students

An important moment in my development as a teacher was deciding what kind of teacher I wanted to become. I distinctly remember riding the MARTA train reading for class about three common types of teachers: the drill sergeant, the consultant, and the helicopter (Fay & Fay, 2016). After giving it some thought, I decided that I wanted my role as a teacher to encompass the consultant. I chose to become the science teacher I wish I had in high school. From that moment forward, every decision I made through my planning, classroom facilitation, and assessment was grounded in how I viewed myself as a teacher. Albert Bandura (1986) stated the belief is the most important indicator in determining how people will act. When it comes to teachers, their beliefs influence how they think about their role in the classroom (Pajares, 1992). Oftentimes the types of beliefs teachers hold about their role in the classroom are categorized into three categories (Porlán & Martín del Pozo, 2004; Simmons et al., 1999; Thomas et al., 2001; Tsai, 2002). Regardless of what the three categories are labeled, they encompass three teaching styles: 1) exploratory, 2) conceptual, and 3) explicit (Buldur, 2017). A teacher who uses an exploratory teaching style focuses on student-centered instruction and views everyone in the classroom as holders of knowledge. Conceptual style teachers focus on giving their students conceptual learning experiences, but are teacher-centered. Teachers who believe students lack knowledge and need to be told information embody the explicit style of instruction (Buldur,

2017). Because beliefs heavily influence practice, how teacher candidates come to understand their role as a teacher during an ITP program is critical (Bahcivan & Cobern, 2016; Buehl & Beck, 2015; Dincer, Goksu, Takkac, & Yazici, 2013; Fives & Buehl, 2016).

Eulsun Seung, Soonhye Park, and Ratna Narayan (2011) examined how elementary science teacher candidates' beliefs about the role of a science teacher and teaching shifted when taking an elementary science methods course. Through analyzing metaphor writings of 106 teacher candidates, three themes emerged: 1) traditionalist view, 2) constructivist view, and 3) neutral view (Seung et al., 2011). Teacher candidates who think in the traditionalist view focused more on the process of teaching rather than student learning. Prior to the course, 57 percent of teacher candidates espoused traditionalist views. At the end of the course only 13 percent subscribed to a traditionalist view. Those who used a constructivist view focused more on student learning and the learning environment. Eleven percent of participants initially aligned with this type of view. Yet, by the end of the course 58 percent described a constructivist view. Table 2.1 shows the explicit beliefs found under each view type.

Table 2.1

Teacher candidates' beliefs about the role/image of science teacher/teaching

#	Traditional view (T)	Constructivist view (C)	Neutral (N)
1	Transfer knowledge and information	Give students an opportunity for exploration	Make class fun with enthusiasm/ positive attitude
2	Guide/lead students with authority	Understand/adjust to students' needs and level of learning	Exert a great deal of effort in preparing a class
3	Take care of students	Scaffold/facilitate students' learning	Learn from experience as a life-long learner
4	Manage and control the class	Nurture students by providing a desirable learning environment	Develop various teaching methods/ skills
5	Mold/transform students' minds to obtain desired products	Encourage students' interactions with peers/teacher	
6		Probe students' preconceptions and connect these to the learning process	
7		Give students autonomy to choose what they want to know	

Source: Seung et al., 2011.

The neutral view was for views of science teaching and teachers that did not fit into the traditionalist or constructivist view. This included a mixture of traditionalist and constructivist views. The percentage of teacher candidates who utilized this view stayed consistent at 34 percent throughout the methods course (Seung et al., 2011). This finding indicates the shifting of beliefs around science teacher roles includes a transition stage where teacher candidates hold conflicting beliefs. Elizabeth Hancock and Alejandro Gallard (2004) examined how science teacher candidates viewed themselves as teachers through drawings. Participants were asked to draw a picture of themselves as science teachers and of someone learning science. They were also asked to include a written explanation for each drawing. The science teacher candidates completed this activity at the beginning and end of the semester. Five case studies were formed during this investigation. Hancock and Gallard (2004) found teacher candidates held and were trying to work through a duality in 1) experience for understanding and transmission for memorization, and 2) student-centered and teacher-centered instruction. At the end of the study, science teacher candidates were able to recognize the conflict they were experiencing in shifting their thinking from the experiences they had as a science student to what research and theory show is best for their students. The ideas about how teacher candidates view themselves as teachers is strongly tied to how they think about students and their learning (Smith, 2005).

While going through my ITP program and as a classroom teacher, whenever I was trying to think about how to best teach a concept to my students, I often thought back to my experience as a science student. In my case, I strived to do the opposite of what my high school science teachers did. Unknowingly, this set me up to stray away from more traditional ways of thinking about learning. However, I still participated in what Dan Lortie (1975) calls the “apprenticeship

of observation." Teacher candidates have spent at least 16 years in the presence of teachers, watching, judging, and noting how their teachers instructed and assessed their learning. They have formed opinions about what they enjoyed as a student, what they would never want to experience again, and how people best learn. This phenomenon leads in-service teachers to often repeat practices their teachers enacted (Lortie, 1975). Because of this, teacher candidates often encounter a dissonance between their prior experiences and what their ITP program presents about students and their learning. When science teacher candidates enter an ITP program, they often think they know little to nothing about the art of teaching (Russell & Martin, 2014). Yet, science teacher candidates enter ITP programs unaware of their initial beliefs about what they will learn around science instruction. They are even more "unaware that they were learning a great deal about how to teach science" while in school (Russell & Martin, 2014, p. 871). The experiences teacher candidates had while learning science in school shape their understanding and expectations of their own classroom practice (Richardson, 1996). Hancock and Gallard (2004) found this to be the case with their participant Diantha, who struggled with reconciling how she was taught science (through transmission) with what her ITP program immersed her in (experiential learning).

An aspect of this study was examining how science teacher candidates alter their practice throughout their ITP program. Extending from teacher candidate thinking are the planning, instructional, and assessment decisions they make. Instead of focusing specifically on their beliefs or practices, this study examined how teacher candidates holistically approach a shift in their thinking around teaching and learning while in an ITP program. The studies above highlight the alignment teacher candidates make during their ITP program in how they view teaching, learning, and their students' abilities. Yet, they only focus on how the program is

influencing teacher candidates thinking. My study explored this, but took into account the various personal factors that impact how teacher candidates think about their role in their students' learning. While teacher candidates strive to learn more about planning, instruction, and assessment, all of this can be for not, if they struggle with their content knowledge. For this particular study, they worked to become fluent in science and the instructional practices that support student learning.

Instructional Practice

Teacher beliefs are hard to understand because teachers themselves are often unaware of their own beliefs (Tobin & McRobbie, 1997). Because of this, it becomes more difficult for teachers and teacher candidates to recognize the impact their thinking has on their instructional practices. Yet, teacher beliefs about their students' abilities and understanding inform how they encourage sense making by students. In Pimentel and McNeill's (2013) study focused on whole-class discussions, they found teachers placed the blame for limited student talk on the lack of student knowledge or resistance. Teachers also mentioned they did not always feel capable of engaging students in whole-class discussions. The impact of teacher beliefs about student science talk extends to their understanding of students' social class as shown by Katsh-Singer et al. (2016). In this study, teachers who worked in high, mid, and low socioeconomic status schools were interviewed about their beliefs around argumentation. Katsh-Singer et al. (2016) discovered teacher beliefs about their students' capability impacted their usage of student talk moves and argumentation in their classrooms. Teachers in schools of low socioeconomic status tended to believe their students were not capable of participating in science talk. The beliefs teacher candidates begin to shape around their students also appear in their practice.

Amelia Wenk Gotwals and Daniel Birmingham (2016) conducted a study to examine the extent science teacher candidates altered their implementation of formative assessments during their ITP program. They collected participants' coursework centered on teaching cycle, lesson plans, and teaching videos produced during their ITP program. Teacher candidates shifted in the focus of classroom practices from fixing purely on the teacher moves to becoming more balanced between the teacher and student. This was seen by teacher candidates including students' ideas, responses, and beginning to embrace responsive teaching. The participants also grew in how they elicited students' ideas. Initially, almost all teaching interactions followed an IRE format and situated the teacher candidate as the intellectual authority in the classroom. Yet, in the spring semester the majority of participants had shifted their questioning to include probing questions or reflective tosses. The final pattern that emerged was how teacher candidates conceptualize students' ideas. Teacher candidates thought of their students' ideas as either correct or a misconception. This dichotomy of thought did not change during the ITP program (Gotwals & Birmingham, 2016). However, when Kang (2008) investigated how science teacher candidates demonstrated their beliefs in their practices, she found three patterns. Eleven teacher candidates acted on their thinking from the beginning of the ITP program and seem to have used their courses as to discover ways to enact their beliefs. Thirty-five percent (8) of the participants grew in their knowledge and goals for teaching. Two teacher candidates implemented practices that were less sophisticated than their initial beliefs demonstrating a regression in their beliefs (Kang, 2008). These findings show the majority of science teacher candidates did not have a shift in their beliefs or practice during the ITP program. Kang (2008) and Gotwals and Birmingham (2016) studies demonstrate how deeply teacher candidates' beliefs revealed in their practice.

Instructional practices are integral to the classroom. The decisions teachers and teacher candidates make around them reveal how they think about learning, their students, their content, and their role as a teacher. The aim of this study was to observe what practices teacher candidates enact in order to better understand their alignment or resistance to educational ideologies in science. Each study above collected lesson plans, writings, and observed the teachers or teacher candidates actively teaching. These collection methods will occur in this study and are expanded on in chapter three. While teacher candidate thinking is the center of change in the classroom, they cannot enact change unless the contextual factors that surround them support reform.

Teacher Candidates' Contextual Factors

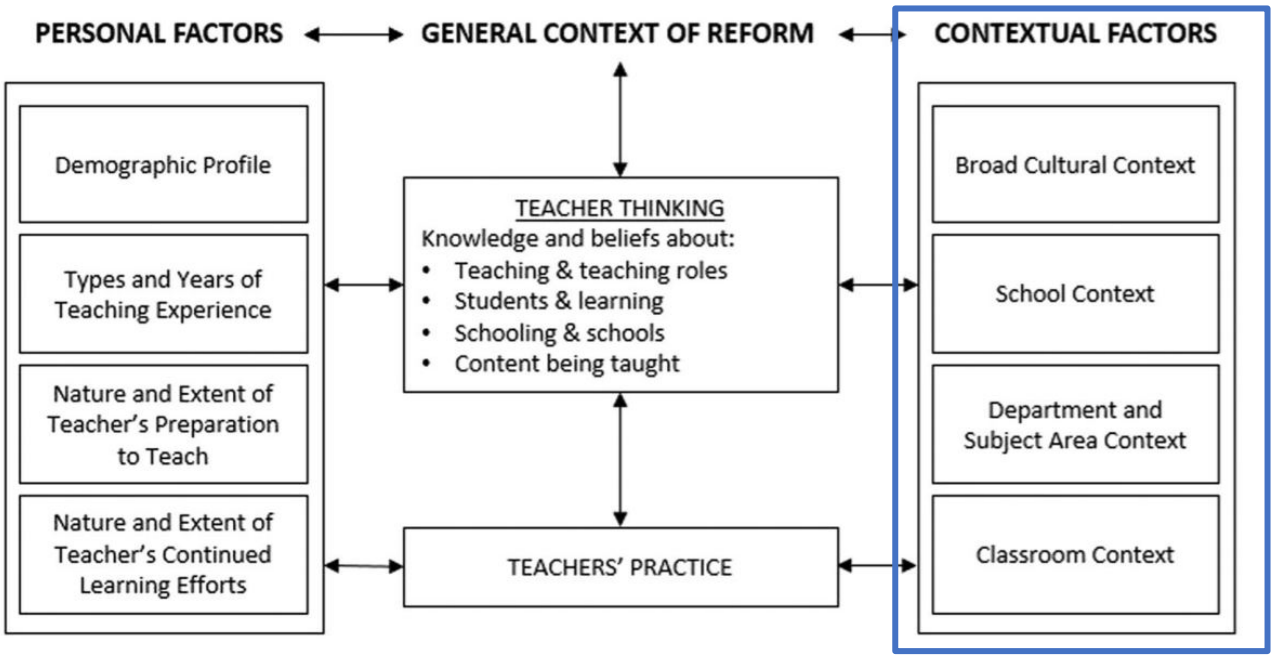
The picture above shows my classroom. There are many things to notice: the students, the clutter on the lab bench in front, the brightness, and more. Everything and one in this picture contribute to contextual factors in the TCSR model (Figure 2.6). The physical environment such as the structure of the building, the fact that my room is mostly lab benches and the windows all contribute to the context of the classroom. Classroom context is generated through the physical, psychological, and temporal characteristics of a classroom (Cuban, 1993; Hargreaves, 1994).

This extends out to the resources available to the classroom, such as curriculum and textbooks. Further, the classroom is part of a larger system that stems from the school to the district to the state and then national levels of education (Woodbury & Gess-Newsome, 2002). Functioning within these systems are individuals fulfilling the roles of students, teachers, administrators, and policy makers.

The culture of a school is also included within contextual factors. The school layout, schedule, type of school, demographics of the community, students, and staff all contribute to the culture of a school. School culture is impacted by its leaders, like the principal, who set expectations, tone, and funds (Fullan, 1991; Leithwood, 1992). Departments within the school also impact the culture of it. Through their acceptance of directives set forth by school leadership, the number, experience, and frequency of meetings, departments can either undermine or support initiatives within the school and district (Siskin, 1994; Talbert & Perry, 1994). In this section, I acknowledge the broader cultural contexts in education that influenced the ideologies teacher candidates brought and challenged during their ITP program. Then, I spend time focusing on a theme that is seen throughout all levels of contextual factors, curriculum, and how teacher candidates interact with it. I expand on school culture and how it impacts teacher candidates. Finally, I explain how this study fit into the literature.

Figure 2.6

Contextual Factors in the Teacher-Centered Systemic Model



Broader Cultural Contexts in Education

Race is a relatively new concept in the history of humanity (Fleming, 2018). The idea of organizing humans based on their skin color took power in the 1400s as the Americas' colonization began to occur (Fernández-Armesto, 2014). It has been used since then to justify oppression, slavery, and systems of disenfranchisement. Race was developed by humans and is believed to be socially constructed. The ideas and beliefs about race continue to shift and morph with society as new ideologies and experiences enter cultural contexts (Morning, 2009). These ideas influence how society defines different races and the beliefs or stereotypes individuals carry about those who look different from them (Fleming, 2018). To better understand how these ideologies are internalized and enacted, Amanda E. Lewis (2003) explored how children come to know about race through their experiences during school in *Race in the Schoolyard: Negotiating*

the Color Line in Classrooms and Communities. During the 1997-1998 school year, Lewis split her time between three California elementary schools: Foresthills, West City, and Metro2. She was placed in fourth-/fifth-grade classrooms in each school and entered different spaces found within schools, such as the lunchroom, faculty meetings, and PTA meetings. This allowed her to become familiar and build relationships with the various stakeholders who were involved in the school. The three schools were selected purposefully due to their contexts. Foresthills was a suburban school with a mostly homogenous student and faculty/staff population. West City was an urban school with a diverse student population but a relatively homogenous faculty and staff. Lastly, Metro2 was an alternative urban school with a focus on bilingual education. This school had the most heterogeneous student and faculty/staff population between the three. Lewis' experiences were varied from school to school when addressing race.

Students and faculty/staff at Foresthills Elementary were mostly categorized as White. During her time there, Lewis observed the teachers actively avoid discussing race or the implications race can have on an individual's life. This was seen in the experience of Sylvie, a biracial girl, who was often confronted by students about her race but could not find support from the faculty at her school. Lewis's experience at West City demonstrated how students learn about race from seemingly innocuous actions. Like Foresthills, West City did not actively discuss or directly address race. Instead, students and faculty/staff showed their understandings and beliefs about race through their actions and inaction. Two prominent examples of this emerged when Lewis noticed a pattern in who was being disciplined most often in the school: Black boys. Teachers were unintentionally singling out these students for their behavior in class. Lewis also observed Latinas blending into the background and not being acknowledged by those in authority. These patterns sent silent signals to students about what it means to be a Black boy

or a Latin girl in school.

In Metro2, Lewis found a school that did talk about race. The unique context of being a bilingual school opened the door for a varied curriculum that focused on culture, race, and identity. However, Lewis saw firsthand the difficulty faculty and staff had navigating the needs of their native Spanish speaking students (often Latinx or newly immigrated) and native English-speaking students (usually White, middle class). An example of this occurred when the staff implemented a detention time during recess for students who did not complete their homework. The White parents were generally against the initiative, while Latinx parents supported it. Ultimately, it was decided to eliminate detention during recess. This example demonstrated the power White parents still had in this fairly racially open school.

Lewis argues these three examples demonstrate how schools are places that construct race as it pertains to identity. Lewis also analyzes how interactions between students, teachers, and other stakeholders help develop racial boundaries. These boundaries form between racial categories that may or may not be crossed depending on, in this case, a student's school. Students at West City experienced fixed boundaries in their identities; they were either part of one racial group or not part of other racial groups. At Foresthills, some students could easily cross racial boundaries between White and Asian while those students like Sylvie were confined to being identified as Black. Movement between borders was most permeable overall as Metro2. Students could move between White and Latino easily, but students identified as Black still struggled to cross boundaries. The context in which race was addressed or not addressed caused stakeholders to think about their own racial identity and the accompanying implications. Within each school, students observed how others like them and different from them were treated. The observations and interactions begin to define racial categories and groupings for children.

I always found it strange that I was required to identify my race and level of my parents' education on standardized tests. I could not understand why the teacher needed to know what degrees my parents may or may not have nor why the fact I am White was required on a test about fifth grade material. As I got older I began to suspect this had a role in labeling or placing me in particular categories. I now know my suspicions were correct. Data, like scores on standardized tests, are used to track trends between different groups (Wiggan, 2007). Students may be divided based on their race or ethnicity, socioeconomic status, and parent education level in order to justify student achievement (as defined by those in power) or the lack thereof. A prominent area of research into these groups focuses on the difference between Black and White students' experiences in school and how those translate into achievement.

Greg Wiggan (2007) reviews literature that addresses why there is an observed difference in student achievement based on race. Through his review, he is able to group the literature into four different themes: (1) genetics deficiency, (2) social class and cultural poverty, (3) teacher expectancy, and (4) student oppositional identity. Wiggan (2007) presents the different arguments for each theme and counterarguments that are found in the literature. There are limitations to each theme, which Wiggan explores. However, he notices that student voice is not included in the majority of studies. Because of this, Wiggan (2007) believes an important theme has not been thoroughly explored: differential treatment of students. This particular theme combines educational quality and emphasis on standardized testing to understand why there is a difference in student achievement. For this response, the two themes of differential treatment of students and social class and cultural poverty will be discussed and critiqued.

In her memoir, *When They Call You a Terrorist* (2017) Patrisse Khan-Cullors unfolds pivotal moments throughout her life that lead to the #BlackLivesMatter movement. The first half of her memoir focuses on her childhood and adolescence which inevitably includes experiences in school. One of the striking stories Khan-Cullors shares is when she was arrested at the age of twelve for smoking weed. It was in this moment, Khan-Cullors (2017) realizes "while we [Black and White girls] can behave in the same or very similar ways, we are almost never punished similarly" (p. 26). Khan-Cullors attended middle and high school outside of the community where she lived thanks to a voucher program. At these schools she witnessed many White students break the rules but never be fearful of the consequences; this reality was the opposite of what Khan-Cullors observed in her community. This particular instance highlights the theme of differential treatment of students. While all students are expected to perform the same, they are not treated the same (Wiggan, 2007). Wiggan focuses this idea on student achievement, but Khan-Cullors' experience demonstrates a lack educational equity between races extends beyond the measure of achievement.

Eve L. Ewing (2018) explores the relationships between schools, the communities they serve, and the politics of school success in her book *Ghosts in the Schoolyard*. Ewing (2018) focuses on the mass school closures that take place in Chicago during the early 2010s. With the exception of one or two, the schools served Black communities in Chicago's south side. The reason given by political officials for closing the schools was many schools were underutilized and under resourced. School board officials used the lack of student achievement on standardized tests to identify schools and label them as failing. Throughout the book, Ewing shows how assumptions have been made by the school board about the communities and their

children which the schools featured serve. These assumptions speak to the literature Wiggan (2007) presents for the theme of social class and cultural poverty. Within this theme, researchers seek to "link social structural and school related factors to the social class structure" (Wiggan, 2007, p. 314). It was assumed because of the lower socioeconomic status prominent in the communities with failing schools, parents would not resist the closures or even know how to resist. The argument that parental education level and class influences student achievement is pivotal to this theme. This assumption revealed itself when many school board members were surprised by the organization and push back from parents of students who attended schools slated to close. While research has shown the relationship between class and achievement, this relationship is based on a hegemonic definition of success which is based in White supremacy (Wiggan, 2007). If achievement was redefined to include resourcefulness and other funds of knowledge, the relationship may shift.

Part of human nature is to categorize things. This ability has allowed the species to survive and evolve; however, there are drawbacks. Categorization inherently leads to ranking or a hierarchy. The themes presented by Wiggan (2007) demonstrate how this aspect of human nature has led to inequalities and differences in how students experience school. Kahn-Cullors (2017) continues to present ways in which the school system and society has been structured to make a Black girl's experience completely different than that of her White peers. Ewing (2018) illustrated how Black communities have had to work against assumptions and structures designed to keep them disenfranchised. While Wiggan (2007) presents these differences through the measure of student achievement, they can be expanded to encompass the whole experience of students while in school.

The teacher candidates that enter ITP programs have either observed or experienced the

structures found in the educational system that allow power deficiencies and oppression to occur whether through race, gender, ability, socioeconomic status or a combination of factors. They bring with them experiences which have shaped their beliefs, assumptions, and biases as a student when they begin to learn how to be a teacher. An aim of this study was to examine how contextual factors influence science teacher candidates' alignment to ideologies that may be foreign to them. For instance, the underpinnings of critical pedagogy possibly challenged how they have thought about and viewed experiences they have had in education. However, the ways in which teacher candidates are taught to enact subject-specific curriculum, like the Next Generation Science Standards (NGSS) can determine how they implement it.

Next Generation Science Standards

Twenty states and the District of Columbia have adopted the NGSS and 24 states have developed their own standards based on the recommendations found in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Science Teaching Association [NSTA], 2021). By having either adopted these standards or designed their own based on the principals inherent in NGSS, 42 states and the District of Columbia have implemented or developed a curriculum incorporating the three dimensions of science teaching and learning (Lowell et al., 2021). Science teachers and teacher candidates in these states are expected to plan, instruct, and assess based on the curriculum set forth by the district, state, or nation. However, McNeill et al., (2017) found that science teachers who are provided well-aligned NGSS curriculum may make decisions that revert instruction back to being teacher-centered. Benjamin Lowell, Kevin Cherbow, and Katherine McNeill (2021) completed a study on how well commercially available curriculum aligns with the NGSS. Out of 23 lessons, they found 70 percent had students engage in zero or one dimension. The other 30 percent had

students engage in two dimensions. None had students engage in all three dimensions (Lowell et al., 2021). These findings are in line with a literature review on how alignment of assessments, curriculum materials, and instructional practices in unpacking NGSS conducted by Gavin Fulmer, Jamie Tanas, and Kathleen Weiss (2018). After reviewing 104 sources (peer-reviewed articles, white papers, reports, etc.), 79 sources focused on interpreting NGSS performance expectations. Twelve documents used a framework that included a referent adapted from NGSS to aid in alignment. The rest focused on defining and applying alignment (Fulmer et al., 2018). Overall, Fulmer et al. (2018) struggled to find where all three dimensions were used in alignment at once. These challenges faced in curriculum development extend from the national level to individual science classrooms. NGSS has been in effect for over five years, yet these challenges persist. Why?

NGSS aims to shift instruction in the science classroom to position students as doers of science instead of listening and receiving information from their teacher (Miller et al., 2018). This shift calls for teachers to re-evaluate their and students' roles in the classroom. NGSS calls for students to have a role in constructing knowledge in the classroom, or have a greater epistemic agency. In order for this to occur, teachers and teacher candidates need to give students the opportunity to build knowledge (Miller et al., 2018). Emily Miller and colleagues (2018) outline four reasons why shifting towards this type of science classroom is difficult. First, the power structure in the classroom traditionally implies the teacher is the sole holder of content and pedagogical knowledge. Secondly, students have different epistemic positions in relation to each other due to entrenched social and political systems. Third, NGSS is being applied into the larger systems and structures of schooling that include factors of resistance to reform and time. Lastly, the definition of science and what it means needs to be addressed completely in the

classroom rather than continuing to perpetuate falsehoods, like the scientific method (Miller et al., 2018). When it comes to tackling these challenges, major ideological shifts must occur in order for reform to take hold. These shifts can first be initiated with science teacher candidates (Duschl, 2008; Ricketts, 2014). In the following sections, teacher candidates understanding and implementation strategies for each dimension will be examined.

Science & Engineering Practices

The science and engineering practices (SEP) are the first dimension within the NGSS and are focused how students participate in science (Table 2.2). Teacher candidates are currently first exposed to the SEPs in their ITP program rather than in the K-12 classroom. They have limited experience engaging in SEPs due to their prior science learning experiences (Windschitl et al., 2008). Because of this, many teacher candidates may experience a disconnect between how they learned to do science and how they are being asked to teach (Crawford, 2014). While teacher candidates are likely to be familiar with the terminology within the SEPs, they may have different understandings of what each term or phrase means (Forbes, 2011). Each teacher candidate brings their own prior knowledge about the SEPs into their ITP program (Windschitl et al., 2008).

This is demonstrated in Tejaswini Dalvi and colleagues (2021) investigate the initial ideas teacher candidates have about the SEPs. They found the majority of participants associated the practice of Asking Questions and Defining Problems as the teacher asking questions rather than students. For the SEP of Developing and Using Models, teacher candidates related this to students being given materials to make a model, and did not differentiate between developing and using models. A similar response was given for the SEP of Planning and Carrying Out Investigations. Teacher candidates focused on students making something with materials and

ignored the difference between planning and carrying out. Analyzing and Interpreting Data was perceived to be based as a time of teacher-led discussion or questioning. Teacher candidates interpreted Using Mathematics and Computational Thinking as students plugging numbers into formula. Interestingly, teacher candidates viewed Constructing Explanations or Designing Solutions as student-centered. Engaging in Argument from Evidence was again thought to be a teacher-led questioning session. Finally, Obtaining, Evaluating, and Communicating Information was thought to be the teacher's responsibility by leading a discussion session (Dalvi, 2021). These findings indicate the various starting interpretations and how teacher-centered teacher candidates' initial thinking is around the SEPs. Yet, as teacher candidates begin to learn about the different SEPs, they start to incorporate them into their planning and instruction (Aminger et al., 2021; French et al., 2018).

Table 2.2

The science and engineering practices with description for science instruction

Attribute	Description
Asking questions and defining problems	Posing questions that can be answered empirically about encountered phenomena, note problems, and their key components so as to indicate potential solution pathways
Developing and using models	Using and constructing representations of natural phenomena to explain and predict, or determine flaws in a system and test aspects of a prototype
Planning and carrying out investigations	Devising a plan to investigate (or test) phenomena of interest and deciding on appropriate data collection procedures and necessary instruments
Analyzing and interpreting data	Using a variety of approaches to properly organize, analyze, and interpret collected data so that patterns can be determined and compared
Using mathematics and computational thinking	Performing tasks such as statistical analysis, simulation manipulation, and mathematical calculations to represent key variables and express their relationships
Constructing explanations and designing solutions	Making evidence-based claims about scientific content and connecting these claims to existing theories to formulate a robust explanation
Engaging in argument from evidence	Identifying the strengths and limitations of claims made about scientific content according to available information, using this evidence to critique the claims and defend such assertions with reasoning
Obtaining, evaluating, and communicating information	Accurately communicating scientific information—in writing and orally—that has been acquired through inquiry, science texts, and mathematical calculations

Source: Brown, 2017

Debbie French and Andrea Burrows (2018) conducted an investigation to better understand how ITP programs alter teacher candidates' focus on the SEPs during their lesson planning. Thirty-four science teacher candidates participated in the study. Students responded to a questionnaire titled "Ideal Lesson Plan Scenario" at the beginning and end of their methods courses. Throughout two methods courses, participants experienced different types of activities related to the SEPs. French and Burrows (2018) found students increased their implementation of Analyze and Interpret Data, Construct Explanations, and Communicating Information (Obtaining, evaluating, and communicating information) the most of all SEPs. Teacher candidates began to incorporate Using Mathematics into their lessons, but this implementation was moderate at best (French & Burrows, 2018). Moderate use of integrating the SEP of Using Mathematics and Computational Thinking into lesson plans by teacher candidates was highlighted by findings from Ameinger and colleagues (2021). They also analyzed the level of cognitive demand the lessons provided for students. Ameinger et al. (2021) focused on six teacher candidates' lessons. Four of the six implemented cognitively demanding lessons focused on Using Mathematics and Computational Thinking. They did this by having students use math to create models of scientific phenomena or having them use math as data for designing solutions to engineering problems (Ameinger et al., 2021).

The dimension of the SEPs in relation to teacher candidates has been well explored by science education researchers. Science teacher educators have a better understanding of how to support their students and what kind of instructional strategies may work best in ITP programs. The studies above demonstrate the change in thinking teacher candidates experience around the SEPs while in ITP programs.

My study supported this research by examining how teacher candidates' practices in the classroom around the different dimensions shifts as they learn more. Another area this study addressed concerning instructional practices was crosscutting concepts.

Crosscutting Concepts

The crosscutting concepts (CCC) are the second dimension found in the NGSS and are meant to "help provide students with an organizational framework for connecting knowledge from the various disciplines into a coherent and scientifically based view of the world" (National Research Council [NRC], 2012, p. 83). While this dimension offers the ability to support students in connecting their scientific knowledge rather than learn concepts in isolation, little is known about the role of the CCCs in student learning (Fick, 2018), how they assist students in building ideas (Chesnutt et al., 2019; Lindgren et al., 2021), and any research related to teacher candidates and the CCCs. While there has been work done around individual CCCs, such as Systems and System Models, this work does not focus on how the CCCs interact with the SEPs and/or disciplinary core ideas (Ben-Zvi-Assaraf & Orion, 2005; Lindsey et al., 2012; Riess & Mischo, 2010; Vachliotis et al., 2014). Because of the lack of literature and research on the CCCs very little, if anything, is known about how teacher candidates think about or implement them into learning. This study has the potential to fill a gap in the literature around the CCCs and how teacher candidates think about them in relation to the other two dimensions. While the focus of this study was not specifically on the CCCs, it provided an insight into how STCs think about CCCs in their practice. Another area that lacks a focus on teacher candidates and their understanding or implementation is the disciplinary core ideas.

Disciplinary Core Ideas

The final dimension of NGSS is the disciplinary core ideas (DCI). This dimension focuses on the content knowledge students learn through K-12 science. The DCI are broken into four types: 1) physical science, 2) life sciences, 3) earth and space science, and 4) engineering, technology, and applications of science (NGSS Lead States, 2013). Literature on the DCIs focuses on how students understand them (Allen, 2010; Chen et al., 2014; Driver et al., 1994), teacher oriented learning materials (Krajcik et al., 2016), or how the DCIs and SEPs are integrated to support student learning (Lehrer & Schauble, 2006; McNeill et al., 2006; Songer, 2006). It is appropriate to find studies examining how these dimensions work together, rather than just focusing on the DCIs. Even so, there is little information about teacher candidates and the DCIs. This may be because ITP programs focus on science content knowledge in addition to pedagogical content. Because of this, most literature around science teacher education is more focused on teacher candidates learning teaching rather than the biogeochemical cycles for example. The curriculum of the NGSS is a contextual factor science teachers and teacher candidates interact with every day. Another contextual factor that is found in the everyday life of teacher candidates during their ITP program is school culture.

School Culture

School culture is often thought to be similar to school climate (Freiberg & Stein, 1999; Hoy et al., 1991; Maslowski, 2006; Owens, 2001; Van Houtte, 2005). In fact, these two terms tend to be used interchangeably (Schoen & Teddlie, 2008). Researchers have debated about the difference between these terms (Anderson, 1982; Hoy et al., 1991). Mieke Van Houtte (2005) describes school culture as part of climate. However, La Tefy Schoen and Charles Teddlie (2008) assert climate is a level of school culture. Through a review of the literature, Schoen and

Teddlie (2008) found the term “school climate” tended to be used in quantitive research, pertain to the physical environment, school effectiveness, and the school social system. For the term “school culture,” they found it to be used more in qualitative research, how the school community views themselves, and the traditions, norms, and expectations (Schoen & Teddlie, 2008). Ultimately, Schoen and Teddlie (2008) determined “the various bodies of research describe different aspects of the same construct and that they all fit together in a complementary fashion” (p. 136). They then devised a new model of school culture with four dimensions. This is seen in figure 2.7.

Figure 2.7

Definitions of the dimensions of school culture

I. Professional Orientation	II. Organizational Structure
the activities and attitudes that characterize the degree of professionalism present in the faculty	the style of leadership, communication & processes that characterize the way the school conducts its business
III. Quality of the Learning Environment	**IV. Student-Centered Focus**
the intellectual merit of the activities in which students are typically engaged	the collective efforts & programs offered to support student achievement

Source: Schoen & Teddlie, 2008

School culture extends and is relevant as a contextual factor in broader cultural contexts. A case that demonstrates this is the use of “school climate” by the state of Georgia as a rating in the calculation of the College and Career Performance Ready Index, which is used to assess schools (Georgia Department of Education, 2021). Students complete surveys about school

connectedness, peer and adult social support, cultural acceptance, physical environment, and social/civic learning (Georgia Department of Education, 2019). Parents also complete surveys, but they respond to questions focused on teaching and learning, school safety, interpersonal relationships, institutional environment, and parent involvement (Georgia Department of Education, 2019). Lastly, student attendance is taken account for the rating. This measurement falls into line with the research around the significance of school culture enhancing school effectiveness (Heck & Marcoulides, 1996; Sammons et al., 1995). Yet, the voices of school staff and leaders are not included in the "school climate" rating. This goes against research that states the culture of an organization reflects the beliefs and norms of employees and is transferred to students (Deal & Peterson, 1991; Peterson, 2002). Since teacher candidates are part of the school community they also have a role in and can be influenced by school culture (Cherubini, 2008).

Lorenzo Cherubini (2008) conducted a study to investigate how teacher candidate beliefs about the culture and climate of schools may shift throughout their ITP program. Seventy-five teacher candidates completed a survey prior to their initial practicum experience that was part Likert-scale and open-ended questions. They completed a post survey in the last week of classes for their ITP program that included the same Likert-scale and different open-ended questions from the first survey. Cherubini (2008) found teacher candidates had much higher expectations of affective attributes related to the school culture and climate. This was especially noticeable in relation to the professional nature of teachers' conversations and how included teacher candidates felt. After completing a two-tailed t-test on the survey results, Cherubini (2008) found a statistically significant difference in teacher candidates' responses in respect amongst the staff, honesty and empathy towards students, professional demeanor, and spirit of inclusivity. Claire Crooks, Peter Jaffe, and Arely Rodriguez (2016) used a similar method as Cherubini (2008) in

their study evaluating the impact of a course for teacher candidates about school climate. Four hundred and eleven teacher candidates took a pre- and post- course survey. Analysis of the surveys found an increase in teacher candidates' knowledge about bullying and an increase in their self-efficacy for responding to student exposure to violence (Crooks et al., 2016). However, the measurement of moral disengagement decreased overall, but did increase for one subset of teacher candidates. Male teacher candidates showed a higher level of moral disengagement than female students. Crooks et al. (2016) make the argument that a course about factors of school climate should be integrated into ITP programs.

Overall the literature investigating teacher candidates and school culture or climate are limited. After searching several databases, I was unable to find studies that spoke to the impact school culture has on teacher candidates outside of the ones presented here. Therefore, my study is highly needed in this area of the literature. The dimensions of school culture (Schoen & Teddlie, 2008) were a part of the analysis of how contextual factors influence science teacher candidates to shift or resist using critical science pedagogies in their teaching. Based on the literature presented above, school culture also has the potential to influence teacher candidates' practice. While I was not able to find an article about this, beginning or induction teachers' practice is known to be impacted by school culture (Bryk et al.,1999; Bryk & Driscoll, 1988; Johnson, 1990; Lee et al., 1993; Talbert & McLaughlin, 1996). Because schools represent a community where beginning teachers fulfill academic, professional, and sometimes extracurricular program roles (ex. Coach), they are quick to take-up the mutual values and types of social relations present (Bryk & Driscoll, 1988; Lee et al., 1993). A positive collaborative school faculty leads to improvement in pedagogical knowledge for beginning teachers (Johnson, 1990). Beginning teachers' practice can be altered when they are part of professional

communities, have positive social relations, and take on reciprocal responsibilities in schools (Bryk et al.,1999; Talbert & McLaughlin, 1996). School culture was examined during my study in relation to teacher candidates' changes in practice throughout the ITP program. However, I could not examine school culture or any other contextual factors by themselves. In order to understanding how all the aspects explored in this literature review interact with each other to inform science teacher candidates' actions in the classroom, a model is needed.

Critical Learning for Systemic Reform Model Expanded

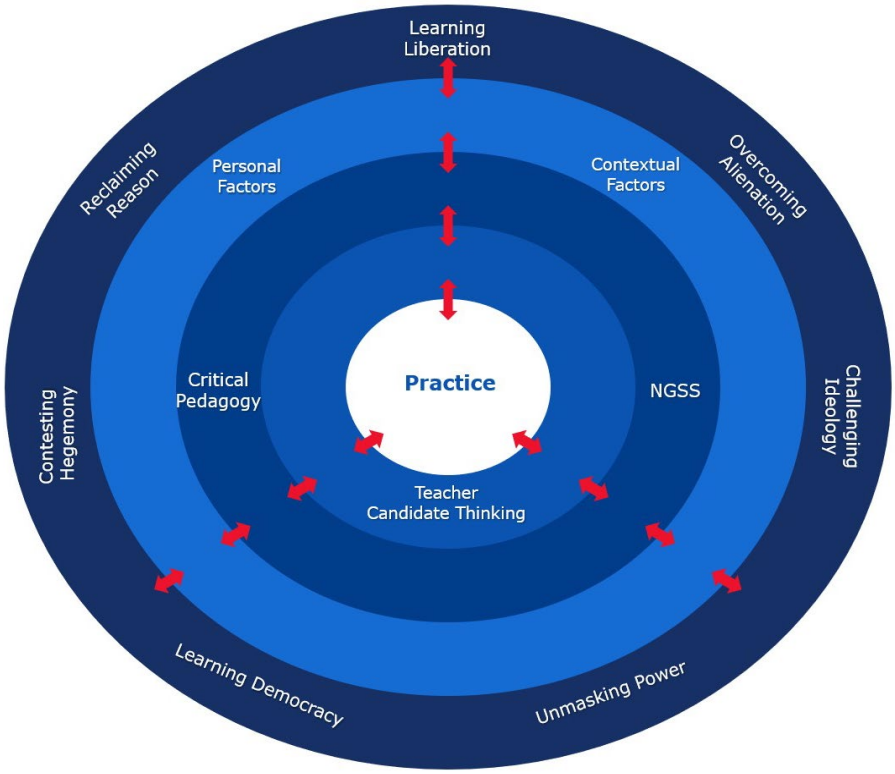
Highlighting the strengths from Brookfield's (2005) critical learning tasks and the elements of the TCSR (Woodbury & Gess-Newsome, 2002), I propose a dynamic and holistic model of shifting ideologies towards reform. The Critical Learning for Systemic Reform (CLSR) model (Figure 2.8) goes beyond combining these two frameworks by suggesting ideologies like NGSS and critical pedagogies are an integral aspect of teacher candidates determining their classroom practice. The CLSR model recognizes the interaction between teacher candidates' thinking, educational ideologies, structural contexts and personal factors, and learning to be critical thinkers that are demonstrated through classroom practice.

The CLSR model recognizes that each aspect explored in this literature review influences teacher candidates' practice, but practice also impacts these elements as well. This is shown by the placement of "practice" in the center of the model. The outer layer is of critical learning tasks. As teacher candidates go through the process of becoming aware of ideologies, questioning hegemony, reflecting on power, recognizing alienation, experiencing dissonance that leads to liberation, developing reasoning, and learning democracy, they then take action to bring about change. Personal and contextual factors are linked through culture; the culture of the structural systems and the culture experienced personally. Ultimately, this reflects in the type of

culture teacher candidates bring and integrate into their classrooms through their practice. The educational ideologies of NGSS and critical pedagogies are grounded in the practice of teaching all students. Meanwhile, teacher candidate thinking centers around how students learn best and incorporating practices based on students. Yet, practice is not the only element influencing the different layers of the CLSR model.

Figure 2.8

The Critical Learning for Systemic Reform Model



The order of the layers of the CLSR is not random. In order for teacher candidates to embrace practices that bring about reform, they must first become critical of the different systems and structures that surround them. This means they need to have opportunities to experience the four critical learning tasks explored in this literature review. Through

experiencing all learning tasks, teacher candidates are able to better understand and become aware of the contextual and personal factors that influence their ability to align with critical science education pedagogical ideologies. For this to take place, they must be willing to acknowledge the educational ideologies in which they function. Once teacher candidates do this, their acceptance and willingness to implement reform based practices increases. Yet, in order for these practices to be enacted on a deep level, teacher candidates have to examine their thinking around the topics covered in "Teacher Candidates' Thinking" in this literature review. However, this is not strictly a one-way model. The CLSR model recognizes this is a fluid process and experiences with each layer impact the other. This is shown through the arrows found connecting the different layers.

Overall, the CLSR model is needed to better understand how and why some science teacher candidates enact reform-minded practices and other choose not to embrace these ideas. Each of the layers and the interactions that take place in the model show how dynamic the learning process and change that occurs during an ITP program for science teacher candidates. If teacher candidates are unable to fully participate or understand a level within the CLSR then they may display various types of enactment of these ideas within their practice. In order to better understand what this looks like, and to observe the CLSR in practice, I designed a study to examine why science teacher candidates align with or resist critical science education pedagogical ideologies and how this alignment or resistance appears in their practice.

3 METHODOLOGY

This qualitative study examined how personal and contextual factors influence secondary science teacher candidates' acceptance or resistance to shifts in ideologies around social justice and science pedagogy. Specifically, this study explored how secondary science teacher candidates alter instructional practices throughout an initial teacher preparation program to align with critical science education pedagogical ideologies. The research questions were as follows:

1. Why do secondary science teacher candidates align and/or resist critical science ideologies?
    a. How do personal factors of teacher preparation influence teacher candidates' shift with critical science ideologies?
    b. How do contextual factors of teacher preparation influence teacher candidates' shift with critical science ideologies?
2. What role does shifting ideologies have in secondary science teacher candidates' willingness to implement new instructional strategies in their classrooms?

In this chapter, I acknowledge my subjectivity and how it has led me to research education ideologies. Following this positioning statement are the epistemological and methodological frameworks guiding this study. I then describe the overall design and process of analysis for this study using a descriptive case study to explain the critical features of secondary science teacher candidates' experiences in an initial teacher preparation program. The chapter closes with how I ensured trustworthiness in findings within the study's boundaries.

Subjectivity

Our position in society determines how we see the world (Valenzula, 2016). My positionality is one of privilege, wealth, and safety. I was born into a White, middle-class, southern family full of teachers. I was raised with the belief that success is tied to education. My parents wanted me to achieve more than them in life. I remember my dad saying, "I want you to be better than me. I want you to have and achieve more than I could." The day I told my parents I wanted to be a science teacher was a day of disappointment for them, particularly my father. This disappointment was rooted in concern because they knew what I would encounter as a teacher.

Their disappointment in my decision drove me to be the best version of a science teacher I could be. I attended professional developments, taught workshops for students on the weekends, engaged in action research, presented at conferences, and became a teacher leader in science for our district. In 2016, My district selected me to be a Science Ambassador, which meant I would work with the state to introduce a new science curriculum to teachers. It was during the first four-day professional development that my entire pedagogical world was rocked. The workshop introduced me to 3D teaching and learning. The dissonance I felt about my often teacher-centered instruction bubbled to the surface and made me question why I teach science the way I do. The following school year, I completely altered my practice and became an advocate for 3D teaching and learning in my district.

Over a year after my pedagogical world was rocked, every other aspect of my life was dramatically altered. My bubble of White privilege and safety burst with a viral video of my father spirit murdering a young Black student (Love, 2019). It was my turn to be disappointed in him. While the fallout from this event was traumatic, it removed the covering from my eyes and showed what truly surrounds me: systemic racism (Bennett deMarrais & LeCompte, 1999; Love,

2019). I began to reflect on my experiences with students. At the beginning of the school year, I would say, "I don't care what color you are. I strive to treat and teach everyone the same." My father would say that, too, and look where it got him. By failing to recognize the racial identities and historical legacies attached to them of his students and himself, my dad re-enacted oppressive behavior in his classroom.

Once I became a full-time student and advanced through my studies, I began to understand the importance of acknowledging every aspect of my students' identities and the need to incorporate my students' cultures into lessons (Love, 2019; Muhammad, 2020). I needed to see all of them. This realization has carried through in my work as a science teacher educator. I work with future teachers to help them understand the importance of social justice in the science classroom and how to implement it in meaningful ways through 3D teaching and learning. Ideological shifts became the hallmark of my journey as an educator, making me a better teacher for my students. I believe that without incorporating both social justice and 3D teaching and learning in the science classroom, the teacher is not instructing the whole student; they only educate the parts of their student to which they most relate. Unlike my experience, current secondary science teacher candidates are exposed to a combination of social justice and 3D teaching and learning ideologies while honing their craft. This study sought to understand the factors that influenced shifts in secondary science teacher candidates' ideologies and how those appeared in their practice.

Epistemological Framework: Social Constructionism

"Being constructionist/constructivist has crucial things to say about many dimensions of the research task. It speaks to us about the way in which we do research. It speaks to us about how we should view its data. We will do well to listen."

Michael Crotty, 1998, p. 65

All my life, my father built things. It could be simple, like a birdhouse, or more complex, like a storage building. He taught me that while you can always buy something, constructing it yourself gives you a much deeper appreciation and connection to the piece. When I first encountered social constructionism, I found a way of knowing that aligned with this value. This way of knowing focuses on the interactions between humans that construct meaning and, therefore, knowledge through experiences shared in a given social context (Crotty, 1998; Bennett deMarrais & LeCompte, 1999). It is the culture, however, that determines what knowledge and meaning are valuable and thus passed on to the individual. Social constructionism asserts no objectivity; all meaning is determined by experiences, interactions, and culture (Crotty, 1998). Often used interchangeably, the term constructionist is distinct from constructivist. A constructionist focuses on how a group develops knowledge, while a constructivist looks at how individuals gain knowledge. Both work to support each other yet focus on different levels of interaction (Crotty, 1998). Grounding this study in social constructionism/constructivism has several implications for research design and analysis.

The design of this research project sought an explanation for participants' behavior rooted in their ideological alignment. Through the epistemological framework of social constructionism, I assumed the ideologies participants hold were learned and developed in the culture in which they exist. These ideologies are shaped and colored by the larger cultural values and meaning.

While culture highlights aspects of our lives we want to see, it also causes other contexts to be ignored (Crotty, 1998). Understanding that not everyone has the same experiences or viewpoints is essential. Their knowledge was learned and focused differently (Stoller, 2014). For instance, someone who identifies as White will have constructed a different understanding of race than someone who identifies as Black. The meaning of race is not only built through the individual experiences between humans, but those experiences themselves teach that meaning, which contributes to cultural knowledge. This assumption influenced how I designed my research with the knowledge that secondary science teacher candidates' context can affect their acceptance or resistance to the ideologies presented in their initial teacher preparation program.

While understanding the social context secondary science teacher candidates bring into their learning, I also acknowledged the personal factors influencing their sense-making around social justice ideologies and 3D teaching and learning. To do this, I needed to be aware that secondary science teacher candidates are being enculturated into the field of science education (Stoller, 2014). By functioning in an educational context, my participants underwent experiences designed to encourage seeing the world differently (Stoller, 2014). Many experiences they participated in are based on social construction, such as student teaching. Teacher candidates had experiences with teaching and were prompted to discuss those experiences with others, which led to negotiating with themselves (Wertsch, 1994). The initial teacher preparation program draws heavily from Lev Vygotsky's learning theory and his thoughts around the zone of proximal development, which influenced the data collection types chosen. (Vygotsky, 1978). Classroom observations, course observations, reflections, and interviews gave richer insight into how participants constructed meaning and knowledge around critical science education pedagogy. Ideologies composed of cultural pressure and individual experiences often provoke

resistance/inertia to accepting new ideas. By viewing contextual and personal factors through constructionism and constructivism, I employed a framework that better understood ideological uptake.

Critical Theory Methodology

The alignment of secondary science teacher candidates' ideologies informed this work toward a central understanding of how the ideology of critical science education pedagogy reveals itself in their practice. By choosing to center the ideologies of secondary science teacher candidates, I centered on social constructions of beliefs, power, and hegemony. Therefore, this research is thoroughly grounded in a social constructionist methodological framework. Given this framework, the methodology must contest, challenge, liberate, and unmask the construction of ideologies and how they impact pedagogical practice.

Brookfield (2005) aligns adult learning with becoming socially and politically aware of the inequities and systemic exploitation of others. He termed this the "critical theory of adult learning" (Brookfield, 2005, p. 2). There are seven learning tasks adults need to participate in to develop social and political awareness fully: 1) challenging ideology, 2) contesting hegemony, 3) unmasking power, 4) overcoming alienation, 5) learning liberation, 6) reclaiming reason, and 7) learning democracy (Brookfield, 2005). I centered these seven critical adult learning tasks in this research. The following section discusses the learning tasks and how they pertain to this study.

Challenging Ideology

To challenge an ideology, a person must first know what it is. Ideologies are "systems of ideas and values that reflect and support the established order and manifest themselves in our everyday actions, decisions, and practices" (Brookfield, 2005, p. 67). The first learning task focuses on adult learners identifying ideologies and acknowledging their presence in their daily

choices, decisions, interpretations, and judgments (Brookfield, 2005). The ideology of critical science education pedagogy encouraged participants to challenge the ideologies they had subscribed to. Assigned course texts and subsequent discussions with their peers helped participants begin their awareness of their ideologies. I observed discussions in class, how they spoke about their students' role and that of a teacher's role. Their lesson plans and teaching observations showed how they tried incorporating critical science education ideas into their classes.

Contesting Hegemony

Hegemony is a process that causes individuals to be oppressed through their own beliefs and practices while elevating those with power (Brookfield, 2005; Marx & Engels, 1970; West, 1982). For instance, the belief that girls cannot be successful in science would be a form of hegemony. The second adult learning task outlined by Brookfield (2005) focuses on thinking critically about power and control, one's socioeconomic class position, and true political interests. In this study, participants encountered foundational texts, class conversations, and required assignments, such as incorporating a critical framework into their lessons, that provided opportunities to confront hegemony in their own lives and practice.

Unmasking Power

Within critical theory, power is exerted in two ways: repressive and liberatory power (Foucault, 1982). Repressive power constrains and coerces individuals to its will. Liberatory power animates and activates others to take control of their lives, often occurring in work that counters hegemony (Brookfield, 2005). Both forms of power are present at all times (Foucault, 1982). The focus of adult education is liberatory power (Kreisberg, 1992). Unmasking power occurs when adults recognize they are agents of power, constantly channeling disciplinary power

(Foucault, 1982), but they also possess the capacity to undermine dominant power relations (Brookfield, 2005). This learning task appears in participants' daily interactions in their classroom placement, course readings, lesson planning, classroom discussions, and field performance observations.

Overcoming Alienation

Alienation is "a mode of experience in which the person experiences himself as an alien…estranged from himself. He does not experience himself as the center of his world, as the creator of his own acts" (Fromm, 1956, p. 120). Alienation is easiest seen in the concept of automaton conformity. Adults engage in this process when they are manipulated by societal expectations, leading to them striving to be the same as the majority (Brookfield, 2005). The pressure for conformity comes from the individual and not outside forces. However, alienation can be overcome when an individual learns to have a structuralized view of the world. By seeing how their decisions are framed and influenced by broader social structures and economic forces, adult learners can build an awareness of how ideologies, cultures, and economics work to shape their lives and others (Brookfield, 2005). This learning task appeared in participants' daily decisions to conform or push back on the norm. The primary sources for this task were interviews, reflections, lesson plans, classroom discussions, and field performance observations.

Learning Liberation

Liberation occurs when one overcomes oppression. Herbert Marcuse's work centers around the belief that individuals learn servitude and enjoy the oppression in which they function. The way to liberation from oppression is paved with intense experiences with art. Art provides a new language, unlocking new pathways of thought. Learning liberation (Marcuse, 1969). These experiences can cause individuals to feel estranged from their oppressive

familiarity or one-dimensional thought. Once estrangement occurs, individuals can become politically aware (Marcuse, 1972). For instance, I observed participants using asset-based rather than deficit-based language to describe their interactions and thoughts about students. The adult learning task of learning liberation calls for a change in how individuals experience the world (Brookfield, 2005). Participants encountered this learning task in their readings, learning new terminology, generating lesson plans, course activities, and teaching their lessons.

Reclaiming Reason

In order to use reason, an individual must "assess evidence, make predictions, judge arguments, recognize causality, and decide on actions where no clear choice is evident" (Brookfield, 2005, p. 55). Brookfield (2005) selected Jürgen Habermas' work to ground the learning task of reclaiming reason. Habermas and Marcuse believe reason can be reclaimed to develop a humane democracy (Brookfield, 2005). Much of Habermas' writing focuses on how democracy and freedom are possible for society, but first require reason. Much of Habermas' work centers on the lifeworld. Brookfield defined the lifeworld as "all those assumptions that frame how we understand our experience of life and how we try to convey that experience to others" (p. 238). The adult learning task of reclaiming reason seeks for adults to determine what they value through reasoning. This learning task appeared in participants' interviews, reflections, lesson plans, and field performance observations.

Learning Democracy

Democracy is when adults can "deal respectfully with difference, live with unresolved conflict, and accept that proposed solutions to complex social problems should always be viewed as temporary, as contingent" (Brookfield, 2005, p. 61). A fundamental assumption made when discussing learning democracy is adults are continuously learning. Brookfield (2005) drew upon

Habermas' (1975) thoughts about the learning adults' experience. The main types are nonreflexive and reflexive learning. Nonreflexive learning is not critical and occurs when an adult learns not to resist the dominant culture (Habermas, 1975). Reflexive learning, by contrast, is critical. This type of learning happens when adults question and challenge the status quo through communicating with others who have different perspectives (Habermas, 1975). An aspect of reflexive learning is evolutionary learning. This type of learning must take place for an adult to learn democracy. Evolutionary learning brings about shifts and changes in how individuals function within systems that lead to societal development (Habermas, 1975). Participants encountered this learning task in their placement schools, which appeared in their interviews and reflections.

Critical Learning for Systemic Reform Model

In order to create the CLSR, I combined elements of the Teacher-Centered Systemic Reform (TCSR) model with the critical learning tasks explored above. Each of these learning tasks appear in the CLSR model and impacted teacher candidate thinking, educational ideologies, and personal and contextual factors. How participants encounter and engage in the learning tasks reflects their thinking and practice as science teacher candidates. Personal and contextual factors intersect with elements the critical learning tasks address, such as ideology, hegemony, and power.

Research Design

In this section, I describe the overall design of this study using a descriptive case study to explain the key features of secondary science teacher candidates' experiences in an initial teacher preparation program. Then, I describe and justify the following elements of the research design: research context, participant selection and criteria, instrumentation and data collection, and data analysis methods.

Overall Design of Case Studies

Research questions often suggest, if not determine, the most applicable research method (Creswell & Creswell, 2018). In the case of this study, "how" and "why" research questions were employed where control over behavioral events is not needed, but the focus of the study was on a contemporary event, initial teacher preparation. By meeting these three criteria, a case study is an acceptable form of research design (Yin, 2018). There are many definitions for a case study. Bogdan and Biken (2016) claim a case study is a detailed examination of a single event, setting, subject, or collection of documents. This study focused on a single year-long event: the journey through an initial secondary science teacher preparation program. At the same time, Hancock and Algozzine (2017) state case studies are different from other types of qualitative research due to their "intensive analyses and descriptions of a single unit or system bounded by space and time" (p. 9). My study was bound by time, the 2021-2022 academic year, and the ITP – Victoria Prefecture University setting.

A more in-depth and detailed definition of a case study as a research method is offered by Yin (2018). The scope of a case study should meet two criteria: 1) a contemporary phenomenon (the "case") is investigated in-depth and in a real-world context, and 2) the boundaries between the phenomenon and context may not be clear (Yin, 2018). For this particular case study, the

case was the participants' experiences while in the ITP. The boundaries between their experiences and the context in which they happened are blurred. For instance, do the experiences occur because of the context or is the context altered because of the experience? Yin (2018) cites three specific characteristics of a case study: 1) It copes with a distinctive situation where there are many variables of interest, 2) it benefits from the prior development of theoretical propositions to guide the study, and 3) it relies on multiple sources of evidence resulting in triangulation. The features listed were met. I explored the first feature in chapter two. The other features will be explored in more depth below.

Case studies can be categorized in different ways (Hancock & Algozzine, 2017). A case study design can be exploratory, explanatory, or descriptive (Yin, 2018). Stake (1995) states that case study research designs can be intrinsic, instrumental, or collective. Overall, case studies may be founded in ethnographic, historical, psychological, or sociological orientations (Merriam, 2001). This case study is categorized as an instrumental descriptive ethnography. Instrumental case study research design seeks greater insight into the theoretical explanation underpinning an issue than enhancing understanding of the issue being examined (Hancock & Algozzine, 2017). In addition to being instrumental, this case study can be categorized as descriptive. Case studies that fall into this category are designed to illustrate or explain critical features of a phenomenon within its context (Yin, 2018). Finally, this case study was ethnographic in its orientation. Ethnographic case study research " explores the observable and learned patterns of behavior, customs, and ways of life of a culture-sharing group" (Hancock & Algozzine, 2017, p. 37). Here, the culture-sharing group was the participants themselves. The culture shared will be that of their cohort, college, and university. To best capture the holistic experience of the ITP, I made sure to document participants' behavior, customs, and ways of life as teacher candidates.

Research Context

"We drive each generation of educators and human service professionals to think creatively and to always be one step ahead. [Students] gain the skills needed to promote physical and mental well-being, share expertise with schools and communities and improve the future for those who need it most."

Victoria Prefecture University

College of Education Mission Statement

The initial teacher preparation program this study's secondary science teacher candidates participated in is special to me. The program is in the same department, college, and urban southeastern university where I learned to be a teacher. The science program has changed since I was a teacher candidate, and the focus has realigned to support current research in science education. The science initial teacher preparation program incorporates social justice and 3D teaching and learning into the curriculum. These changes reflect a direct focus on science education research found in the College of Education (COE) mission (see above).

Students who enter the COE are privileged to a variety of support. The Secondary Education Department provides many different scholarship opportunities focusing on supporting learners who have taken a non-traditional path to become educators (Scholarship Resource Center, 2021). Because of these programs and the location of Victoria Prefecture University, graduate students from various socioeconomic, cultural, and racial backgrounds enter the COE and, therefore, the department that serves secondary science teacher candidates (Table 3.1).

Table 3.1

Demographics of Graduate Students across Levels of University to Secondary Science Teacher Candidates

	Victoria Prefecture University	College of Education	Secondary Education Dept.	Secondary Science Method Course 1	Secondary Science Method Course 2	Secondary Science Method Course 2
	n = 7259	n = 1594	n = 342	n = 14	n = 13	n = 13
	%	%	%	%	%	%
Race						
Black	30	40	43	29	39	39
White	43	46	41	35	23	23
Asian	19	7	10	29	39	39
Hispanic	4	5	5	7	0	0
Sex						
Female	64	78	73	85	85	85
Male	36	22	27	14	14	14
Average Age	31	34	35	27	25	25

Source: Office of Institutional Effectiveness (2021)

To help their students " think creatively and to always be one step ahead" (Mission Statement, 2021), the COE worked to ensure the latest research informs their curriculum. For secondary science teacher candidates, this meant incorporating 3D teaching and learning pedagogy into their coursework. Students must complete three 'methods' courses where they were exposed to and instructed in lesson planning, classroom facilitation, assessment, learning theory, and the application of 3D teaching and learning (Course Catalog, 2021). Students utilized

texts such as *Teaching with Love and Logic: Taking Control of the Classroom* (Fay & Fay, 2016) and *Teaching Science to Every Child: Using Culture as a Starting Point* (Settlage et al., 2018). Woven throughout these learning goals were foundational aspects of social justice.

Secondary science teacher candidates did not learn social justice separately from 3D teaching and learning. Instead, they learned how these two ideologies work together in a science classroom to "improve the future for those who need it most" (Mission Statement, 2021). Students encountered Bettina Love's (2019) *We Want to Do More than Survive: Abolitionist Teaching and the Pursuit of Educational Freedom* and Gholdy Muhammad's (2020) *Cultivating Genius: An Equity Framework for Culturally and Historically Responsive Literacy* as their first text in the science methods courses (Enderle, 2020a). These two books laid the foundation for secondary science teacher candidates' work regarding social justice. They were later introduced to culturally relevant and culturally sustaining pedagogy (Enderle, 2020a; Enderle, 2020b), along with texts that exposed students to the histories of racially and socially minoritized groups (Enderle, 2020b; Enderle, 2021). Secondary science teacher candidates were tasked with applying their knowledge to assignments such as unit plans, assessment plans, and narratives for their program portfolio (Enderle, 2020b; Enderle, 2021). The initial teacher preparation program aimed for secondary science teacher candidates to become abolitionist teachers of science.

Participant Selection & Criteria

To answer the proposed research questions, the main criterion for participant selection entailed being enrolled in an initial teacher preparation program focusing on secondary science education at Victoria Prefecture University. The course population was primarily female-identifying, of varying ethnic and racial identities, was younger, and was a mixture of provisional and traditional teacher interns. Ideally, the sample of participants reflected the

population of those enrolled in the course. Participation in the study was voluntary, leading to convenience sampling from the initial science methods course students. Students who chose to participate engaged in the three-course methods sequence and practicum in the fall and spring semesters. Since this is a case study, I sought four or five participants (Creswell & Creswell, 2018).

To recruit participants, I gave a presentation outlining the project, participant responsibilities, time requirements, and why I was studying this topic. The presentation appealed to the need for knowledge about the secondary science teacher preparation process and how to improve the educational experience for future students. I also included information about myself and my education journey. Students asked me questions in person and through email. For the following several class periods, I briefly discussed the study at the beginning or end of class. Participants also needed to be willing to submit artifacts completed in their methods and practicum courses to me. They also participated in four 30-minute interviews over 11 months.

The Teacher Candidates

In total, I recruited seven science teacher candidates; however, I lost two participants due to them leaving the ITP program after the summer methods course. The five remaining participants consisted of three individuals who identified as women and two who identified as men. The science teacher candidates represented the diverse population of their cohort. The two men in the study, Jacob and Tam, were the only men in the cohort. Azula, Starr, and Madelia each represented different age groups in the cohort population. The only population not represented in my participant sample were provisional teacher candidates. While Madelia had been a provisional science teacher the prior school year, she was a traditional teacher candidate throughout the ITP program. Each science teacher candidate was in a different school district for

their practicum experience. Jacob was the only teacher candidate placed at a middle school; the others were in high schools. Table 3.2 below shows the demographics of each participant in this study. The names presented throughout this study are all pseudonyms to protect the identities of the participants.

Table 3.2

Science Teacher Candidates Demographics

Participant	Age	Race/ ethnicity	Experience in classroom	Area of focus	Degree in progress at time of study
Azula	22	Asian/Indian	0 years	Biology	MAT
Jacob	26	White	0 years	Biology	MAT
Madelia	27	White/Greek	1 year	Chemistry/ Physics	MAT
Starr	31	Black	0 years	Biology	MAT
Tam	21	Asian/ Vietnamese	0 years	Physics	BS

In the next section, I introduce each teacher candidate. Their sections start with a quote from the program's first semester, followed by a description.

Azula

"My goal is to allow my students to navigate their own worlds while also providing them with the encouragement and inspiration that they need" (R1).

Outspoken, thoughtful, and ambitious are all words that could be used to describe Azula. Throughout her time in the initial teacher preparation (ITP) program at Victoria Prefecture University (VPU), Azula was an active participant in classes. She consistently shared her

thoughts and opinions about topics discussed and worked well with others. The first methods course, where I was introduced to Azula, was online. Her level of engagement and willingness to share her thoughts helped create an image of a larger-than-life individual in my mind. However, when I first met her in person, I was taken aback by her height. Even with a stature of around 5'2", Azula's energy was unmistakable. As a 22-year-old young Muslim woman of Indian descent with short black hair, a common stance of hands on her hips, and numerous tattoos and piercings, Azula had a presence. She always had her nails done and wore the latest fashions, from her white Doc Martins to a crop top with a high-waisted skirt. Azula could often be heard laughing and encouraging her peers in class while commiserating about the challenges of being a first-generation American with Madelia. She completed the ITP program and taught in her placement district.

Jacob

"My goal as a teacher is to open these students' eyes, and to help them understand that they can do anything that they put their hearts and minds on" (MR1)

A shaved head, handlebar mustache, heavily tattooed, and glasses are several identifiers that could be used for Jacob. Kind, open, and determined are the main words that come to mind when I think about Jacob. Like all the other participants in the study, I was first introduced to him online. Whenever Jacob appeared on my screen, he was surrounded by animals and continually engaged with them while participating in class. Throughout the ITP program, Jacob's contributions to his method classes varied. He was not a dominant voice but still had a thoughtful presence. Jacob positioned himself in the back of the classroom, observing the other students. As much as Jacob attempted to blend in with his surroundings, he could not help but be noticed. Jacob was a 26-year-old White male who stood around 5'10". He was often spotted in a t-shirt,

light jacket, khaki pants, and black Converse shoes. Jacob could often be heard questioning and reflecting with his peers during class. He completed the ITP program and moved to a Western state to teach.

Madelia

"As a teacher, I hope to guide my students and have them think on their own. I would love to ask my students what they thought of the lessons and what else they would like to learn about to give them some control of their own education" (MR3).

The first time I met Madelia, I was overwhelmed by her excitement to learn about teaching science. With a pixie haircut, glasses, and a soothing voice, Madelia revealed she had taught 8th grade science the previous year but was now part of a scholarship program in the department. The more Madelia participated in class, the more curious, fierce, and open she came across to her peers. Madelia emerged as a leader in the methods courses with her prior experience and willingness to take risks with her thinking. Because of this, I was shocked to meet a more petite woman of 5'2" stature in person. Madelia and Azula, along with Starr, became fast friends and support for each other. All three positioned themselves in the middle of the classroom at a table together. Madelia appeared to be sure of herself and often shared personal experiences with others, particularly stories of her adventures with her finance Claire. As a 27-year-old White woman, member of the LGBTQ+ community, and first-generation American, Madelia brought many different experiences and cultures with her to the ITP program. She often wore khaki pants, sneakers, and a collared button-down shirt in class. Madelia completed the ITP program and moved to a Western state to teach.

Starr

"I want [students] to take ownership of their learning by engaging them and allowing them to help make decisions about their learning. Learning is not just about memorizing, but explaining how you got the answer, or what made you ask the question in the first place" (R1).

A former award-winning cheerleader, daughter of teachers, and Uber driver, Starr was a people person. She would easily hold a conversation with anyone and was genuine in her want to connect with others. Starr consistently contributed to the methods class and was the one student who would often ask for clarification. Cautiously courageous, authentic, and driven, Starr quickly connected with Azula and Madelia during the summer methods class. Between the three, Starr was the tallest at 5'5" but the least vocal. As the eldest of the three at 31 years old, Starr often reminded the other two to let others speak in class, exhibiting her nurturing side. Starr was Black, often wore her hair in braids to the middle of her back, always had her nails done, and enjoyed writing using a variety of colors when taking notes. She usually wore jeans, sneakers, a T-shirt, and a light jacket to class. Starr could be heard seeking reassurance from her peers and making sure they stayed on task in class. Starr graduated from the ITP program and taught in her placement district.

Tam

"I believe that all students should have equal opportunity to learn science" (MR3).

The youngest in the cohort at 21 and still an undergraduate, Tam found himself surrounded by others with different life experiences than him. In the summer course, Tam readily admitted areas he wanted to improve his knowledge and listened to those willing to share their thinking with him. A deep thinker, pragmatic, and brave, Tam often had a quiet presence in class

but contributed when asked. Once class transitioned to being in person, Tam positioned himself at the same table with Jacob in the back of the classroom. They could often be heard arguing during group projects and pushing back on each other's thinking. He was around 5'5", had short black hair, and usually wore a black t-shirt, black jeans, and black vans to class. Tam immigrated to the United States at 14 from Vietnam to the city where the study took place. He did not know English when he immigrated, but he was in honors classes by his senior year of high school. Tam was usually a few minutes late to class and was the only student who did not bring a personal computer with him. Tam graduated from the ITP program, along with his physics program, and taught in his placement district.

Instrumentation & Data Collection

Multiple forms of instrumentation were used throughout the data collection process. The data types fall into one of three categories: 1) observations, 2) interviews, or 3) documents (Creswell & Creswell, 2018). I stored collected, de-identified data in a password-protected OneDrive. Participants self-reported all data. The primary data sources included semi-structured interviews, reflective writing from their coursework, and method course classroom observations. Lesson plans, field performance observations, and class artifacts composed the supporting data. Table 3.3 shows how these different forms of instrumentation and data collection align with each research question and my conceptual framework.

Table 3.3

Alignment of Conceptual Framework and Data Collection with Research Questions

Research Question	Critical Theory Learning Tasks	TCSR Model	Data Collection Item
1a. How do *personal factors* of teacher preparation influence teacher candidates' shift with critical science education pedagogical ideologies?	All Critical Adult Learning Tasks	Personal Factors	• Method Courses Observations • Interviews • Reflections • Class Artifacts
1b. How do *contextual factors* of teacher preparation influence teacher candidates' shift with critical science education pedagogical ideologies?	All Critical Adult Learning Tasks	Contextual Factors	• Field Performance Observations • Method Courses Observations • Lesson Plans • Interviews • Class Artifacts
2. What role does shifting ideologies have in secondary science teacher candidates' willingness to implement new instructional strategies in their classrooms?	All Critical Adult Learning Tasks	• Personal Factors • Teacher Thinking • Teacher Practice • Contextual Factors	• Field Performance Observations • Method Courses Observations • Lesson Plans • Reflections • Class Artifacts

Semi-Structured Interviews

Interviews throughout the year were central to the data collection. These interviews were designed to elicit participant ideas and beliefs around social justice ideologies and 3D teaching and learning. Each participant gave four 30-minute interviews throughout the 11-month data collection period. I conducted the interviews over the Zoom platform, recording them with the participant's consent. Interview questions were written to capture participants' beliefs about

science education, teaching, and their understanding of social justice. I drew upon the Teachers' Belief Interview (TBI) developed by Luft and Roehrig (2007) for questions on teacher beliefs around science education and instruction. I pulled previously validated questions from those found to be reliable by Luft and Roehrig (2007). To capture any change in thinking over the four interviews, I repeated several questions at each juncture. (see Appendix A).

The initial interview's purpose was to gather information on participants' reasoning for entering science education, their background, and thoughts about what it means to be a science teacher. These acted as the baseline interviews for this study. The second interview focused on participants' experiences in the summer semester that impacted their thinking about science education. The third interview focused on whether participants made or did not make changes in their teaching during the fall semester. The final interview asked for reflections on their overall experiences in the program. The schedule of these interviews can be found in table three.

Reflective Writing

Participants wrote two reflective writing prompts each semester of the program. The writing prompts were the same for each semester, providing three different responses from each participant for each prompt. Each participant completed the prompts as part of their secondary science methods course. Per the IRB, all responses were self-reported. Table 3.4 outlines when participants were asked to complete the prompts. Focused reflective writing can provide "rich descriptions of how the people who produced the materials think about their world" (Bogdan & Biklen, 2016, p. 132).

The first prompt participants responded to focused on the social justice ideology taught in their initial teacher preparation program. "**How can you cultivate genius in your classroom while being an abolitionist teacher?**" This prompt allowed participants to envision what they

expected their classroom and role as a teacher to look like. Their responses gave insight into their thinking about critical science pedagogy and their ability to implement it. The second prompt highlights the participants of the 3D teaching and learning ideology: "**How does the 3D teaching and learning framework reflect the scientific enterprise? What are the affordances and challenges with this approach to science teaching?**" The answers participants provided to this prompt shed light on how they connect 3D teaching and learning to their own beliefs about science. It also gave valuable insight into how feasible participants believed science pedagogy to be in the classroom.

Field Performance Observations (FPO)

The program required participants' mentor teachers and university supervisors to conduct two observations in the fall and three in the spring, culminating in ten observations. Participants self-reported the observation rubric and provided feedback. Ideally, I would have been able to conduct observations myself. However, due to constraints that COVID-19 placed on schools and teacher candidates, I feel it was unethical to subject my participants to more observations than were necessary.

The tool used for observations focused on four main areas: 1) professional knowledge, 2) instructional delivery, 3) assessment of and for learning, and 4) learning environment (Bhatnagar et al., 2021). This observation rubric was used during participants' practicum courses during the initial teacher preparation program. University supervisors received training on the rubric before the first observations took place. Mentor teachers were introduced to the rubric by the university supervisors at the beginning of each semester. Victoria Prefecture University's COE developed this observation tool. In Bhatnagar et al. (2021), the "rubric possesses strong content validity as well as a good level of inter-rater reliability and internal consistency" (p. 11).

The observation has four levels of scoring: advanced, proficient, developing, and insufficient. An example of the difference between levels of achievement can be seen in Figure 3.1.

Figure 3.1

Observation of Field Performance Rubric Differences in Indicator

	INDICATOR	*Advanced*	*Proficient*	*Developing*	*Insufficient*
	PROFESSIONAL KNOWLEDGE				
1-PK	**Knowledge of the Learner & Identity Development: Builds upon learners' existing academic, developmental, linguistic, personal, cultural/community strengths, needs, and experiences. (Including, but not limited to, race, ethnicity, language, religion, socioeconomic status, gender, sexual orientation/expression, national origin, and/or exceptionality.)**	Maximizes learner's prior knowledge by integrating lesson objectives with learners' academic, personal, developmental, linguistic, **AND** cultural/community strengths, needs, **AND** experiences.	Uses learner's prior knowledge by integrating lesson objectives with learners' academic, personal, developmental, **AND** linguistic, **AND/OR** cultural/community strengths, needs, **AND/OR** experiences.	Uses learner's prior knowledge by integrating lesson objectives with learners' academic, personal, developmental, **OR** linguistic, cultural/community strengths, needs, **OR** experiences.	Does not use learner's prior knowledge by integrating lesson objectives with learners' academic, personal, developmental, linguistic, **OR** cultural/community strengths, needs, **OR** experiences.

Generally, participants score developing to proficient in the summer and fall semesters, and by the spring semester, participants should achieve proficient to advanced. Specific items within the rubric were of interest in the analysis phase of this project, specifically criticality and pedagogical content knowledge.

Method Courses Observations

Observations of each secondary science methods class were conducted during the initial teacher preparation program. Field notes of particular interest were the types of questions participants asked, their responses, and their body language. Field notes also helped document how the ideologies were presented to participants. I had the opportunity to directly observe participants when I guest-led several class periods throughout the summer secondary science methods course on classroom facilitation. After class, I would promptly document my observations. The summer course was synchronous and online, while the fall and spring semesters took place in person at VPU's COE.

Lesson Plans

Students self-reported completed lesson plans from their secondary science methods and practicum courses. Most lessons were completed using the VPU departmental lesson plan template; however, lessons submitted from the summer secondary science methods course were used for participants' alternative teaching experience. The lesson plans aligned with observations from myself, the participants' mentor teacher, or their university supervisor. In total, participants submitted three lesson plans in the summer, four in the fall, and six in the spring.

The lesson plans demonstrated how participants incorporated critical science education pedagogy into their teaching. This was evident throughout the lesson plan but was highlighted in the lesson's learning objective, assessment, and overall design. They enabled me to compare the participants' practice with what they planned and to support the characterization of potential changes in their practice throughout the initial teacher preparation program.

Class Artifacts

Students self-reported additional class documents as they saw fit. Participants were not required to self-report more than was asked, but those items were included as supporting data.

Table 3.4.

Outline of Data Collection by Semester

Semester	Data Collection
Summer 2021	Initial Interview Reflection Prompt 1 Three Lesson Plans Reflection Prompt 2 Methods Course Observations Class Artifacts*
August 2021	2nd Interview
Fall 2021	Reflection Prompt 1 Four Lesson Plans (Completed for FPO) Four Field Performance Observations (Completed by MT & US) Reflection Prompt 2 Methods Course Observations Class Artifacts*
December 2021 – January 2022	3rd Interview
Spring 2022	Reflection Prompt 1 Six Lesson Plans (Completed for FPO) Six Field Performance Observations (Completed by MT & US) Reflection Prompt 2 Methods Course Observations Class Artifacts*
May 2022	4th Interview

*Collected at the participant's discretion.

Data Analysis

As suggested by Creswell and Creswell (2018), data analysis was performed in two stages: a general procedure (Figure 3.2) and a more advanced layer of analysis (Figure 3.3)

specific to case studies. These two processes are outlined below. Figure 3.3 shows how these two processes were combined in my data analysis procedures.

General Analysis Procedure

All data was organized into folders by semester and then separated by participants. All data collection was digital, and no hard copies were maintained outside of a participant code key. This code key document identifying participants and their pseudonyms will be locked in a filing cabinet in my home. As data was collected, I organized it in secure folders on OneDrive. I did not read through the data until it was all collected from participants for the study.

Figure 3.2

General Analysis Procedure for Qualitative Research.

Note: Adapted from Creswell & Creswell (2018)

I coded interviews, reflective writings, lesson plans, classroom observations, and field performance observations at the end of data collection. I based the codes on my conceptual framework (e.g., Personal factors), leaving room for unique or surprising codes to emerge. I generated a codebook for the key aspects of the Critical Learning for Systemic Reform model (see Appendix B). After each participant's data had been coded, I recorded the code frequency for each concept associated with a learning task. For example, Madelia had 67 coded items for ideology. I selected the three highest coded concepts for each participant. From there, I developed descriptions of four critical adult learning tasks that appeared highly for participants:

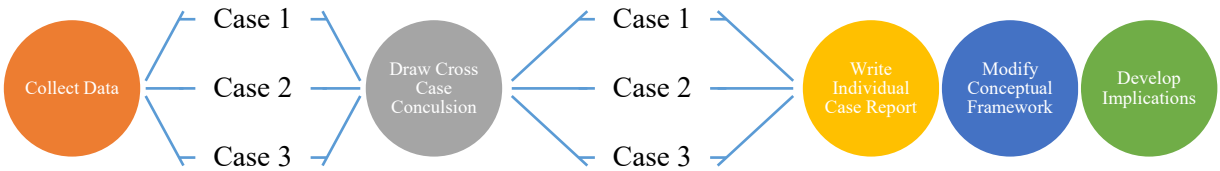
challenging ideology, contesting hegemony, unmasking power, and reclaiming reason. Descriptions for the remaining three critical adult learning tasks were developed based on the experiences of a particular participant

Case Study Analysis Procedure

Individual cases determined data collection for this case study. Collected data was stored and categorized by case and semester. I altered my analysis method to conduct a cross-case analysis before writing individual cases to answer my research questions. This ensured each aspect of the Critical Learning for Systemic Reform model was addressed while determining which critical adult learning tasks were significant for all participants.

Figure 3.3

Case Study Analysis Procedure.



Note: Adapted from Yin (2018).

After conclusions were drawn across cases and individual cases were constructed, modifications to my conceptual framework became clear. I developed implications from this study based on the conclusions and potential conceptual framework modifications made.

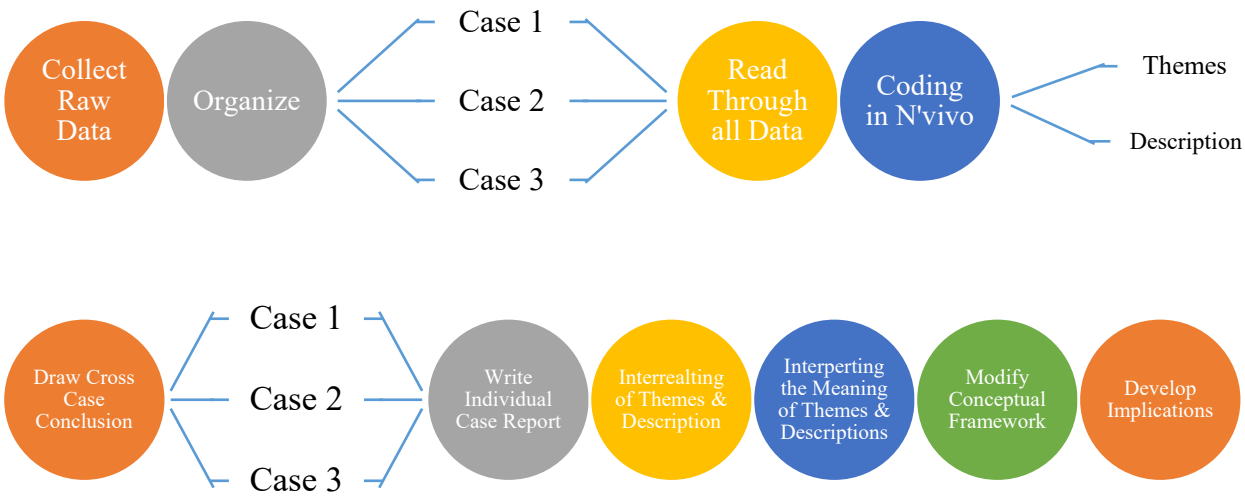
Overall Study Analysis Procedure

Data collection occurred prior to data analysis. While I initially wanted to analyze data during collection, I became concerned that I would become even more biased toward certain participants or ideas in my classroom observations. I opted to analyze data once data collection

was completed. Throughout the data analysis process, I ensured trustworthiness through member checking, thick descriptions, and triangulation of data. This is discussed in further detail below.

Figure 3.4

Overall Study Analysis Procedure.



Note: Modified from Creswell & Creswell (2018); Yin (2018).

Trustworthiness

"Qualitative data analysis is an interpretive task. Interpretations are not found – rather they are made, actively constructed through social processes."

Douglas Ezzy, 2002, p. 73

Validation and reliability are terms associated with quantitative research (Ely et al., 1991). These terms within qualitative research position its findings with a quantitative lens (Creswell, 2007). Instead of using these terms, Lincoln and Guba (1985) proposed using trustworthiness to describe the social process of collecting and analyzing data during qualitative research. Several techniques were used to establish trustworthiness: 1) triangulation of data sources and methods to establish creditability, 2) thick descriptions to ensure findings were

transferable between myself and the participants, and 3) member checking with participants to guarantee confirmability of findings (Creswell, 2007). The following section outlines these employed methods throughout the data collection and analysis.

Triangulation

Triangulation occurs when several different sources of evidence are collected and used during data analysis (Hancock & Algozzine, 2017). Within a case study, triangulation offers several benefits. First, an in-depth and contextual description of a case will form that is supported in multiple ways. Secondly, converging lines of inquiry can emerge (Yin, 2018). If multiple sources of evidence collaborate to support the same finding, then confidence that the case study will show an event accurately increases (Creswell & Creswell, 2018). For this study, three main data types were collected and analyzed: 1) observations, 2) documents, and 3) interviews. All three forms of data were collected each semester and triangulated to build a coherent justification for emerging themes.

Thick Description

Clifford Geertz (1973) uses philosopher Gilbert Ryle's explanation of thick description to expand on the task of ethnography (Bogdan & Biklen, 2016). However, a thick description can apply to many methods of qualitative research (Creswell & Creswell, 2018). A thick description can give "a stratified hierarchy of meaningful structures in which [behaviors] are produced, perceived, and interpreted, and without which they would not, in fact, exist" (Geertz, 1973, p. 7). These descriptions illustrate a shared experience between participants, and they can offer many perspectives about a theme. The collected data holistically illustrated more layers to the participants' expressed experiences in this study. Thick descriptions in this chapter, as well as the personalized analysis for each participant aided in the overall case summary for the participants.

Member Checking

Member checking allows participants to confirm and add information to the data collected. For the researcher, this process refines the accuracy of their findings (Creswell & Creswell, 2018). This process can occur multiple times and in various ways, from showing participants transcripts of interviews to summarizing the findings (Ezzy, 2002). Additionally, in case study research, member checking Yin (2018) suggests providing participants with a draft of the case study, leading to participants sharing new information. For this study, I attempted to have participants read and provide feedback on findings related to their particular experiences. Unfortunately, I did not hear back from the participants before submitting this dissertation. Moving forward, the feedback provided by participants will be addressed as required.

Boundaries

Like any research study, this one has boundaries to its generalizability (Creswell & Creswell, 2018). The following boundaries constrained this case study and must be acknowledged when discussing cases.

1. COVID-19: This study was conducted while a worldwide pandemic continued to impact the everyday lives of my participants and myself. It was important to consider challenges that might have occurred with participants and data collection due to this context. Since participants were working in school systems impacted by changes made for COVID-19, participants were limited in their ability to enact certain practices. This boundary also influenced the additional requirements I felt comfortable asking participants to fulfill. For instance, before COVID-19, I wanted to conduct teaching observations myself; however, this was not possible in this study for several reasons: 1) Participant schools were not

allowing non-school personnel in the buildings, and 2) I always considered the potential impacts on my participants' mental health.

2. Sampling: Due to the type of sampling employed in this study, the sample did not reflect the broader population of secondary science teacher candidates. The participants did not reflect the population; therefore, the findings from this study are less generalizable. However, through rich descriptions with thematic findings, there is the potential to inform other teacher educators with similar teacher candidates.

3. Self-reporting: Throughout this study, participants were asked to self-report their data. This included documents and experiences. Due to this, it was not possible that all proposed data was collected, such as a few reflections and field performance observation results. It is also important to understand and respect that participants did not fully share their experiences or thinking in our interviews. However, trust is an essential component of this type of research.

Summary

Systemic factors such as competing education ideologies, hegemony, power, and oppression work together to maintain the status quo within science education. They appeared in contextual and personal factors throughout ITP programs and the educational system. The experiences teacher candidates had in these realms impacted how they chose to interact with critical science education pedagogical ideologies. The alignment with or resistance to these ideologies impacted teacher candidates' thinking and, therefore, their classroom practice. Accepting or rejecting these ideologies coincided with the instructional practices teacher candidates are willing to undertake in their classrooms.

Throughout my time as an educator, I have always been confused as to why teachers, and now teacher candidates, repeatedly resist new ways of teaching all students science. This was a personal and academic quest to understand why some teacher candidates align with critical science education pedagogical ideologies, and others do not. While the full extent of that question may be unknowable, I believe I have uncovered some unexpected and actionable answers for why some teacher candidates struggle to enact teaching reform. Any insight into the "why" and "how" of this question will allow us who teach teachers to better support teacher candidates in their journey to becoming the teacher they might not know they could become.

4 RESULTS

This chapter presents the experiences of Azula, Jacob, Madelia, Starr, and Tam as science teacher candidates in an ITP program. The study sought to explore why science teacher candidates align and/or resist critical science ideologies while in an initial teacher preparation program. My study employed the Critical Learning for Systemic Reform (CLSR) model to answer the following questions guiding my research:

1. Why do secondary science teacher candidates align and/or resist critical science education pedagogical ideologies?
    a. How do personal factors of teacher preparation influence teacher candidates' shift with critical science education pedagogical ideologies?
    b. How do contextual factors of teacher preparation influence teacher candidates' shift with critical science education pedagogical ideologies?
2. What role does shifting ideologies have in secondary science teacher candidates' willingness to implement new instructional strategies in their classrooms?

In order to answer these questions using the CLSR model, I structured my analysis within the critical adult learning tasks. The first four learning tasks presented occurred across all participants and were significant to their learning in the ITP program. Challenging ideologies, contesting hegemony, unmasking power, and reclaiming reason represent a cross-case synthesis (Yin, 2018). For each case, I highlight two participants' experiences spanning all five aspects. However, it is essential to note that each participant had a unique ITP experience. This becomes evident in the last half of the chapter, where I explore the individual cases of Tam, Azula, and Jacob related to the critical adult learning tasks of overcoming alienation, learning liberation, and

learning democracy, respectively. All cases incorporate participants' practice, personal and contextual factors, and how they engaged in aspects of the learning tasks.

Throughout this chapter, I have used a specific notation indicating the various forms of data used in analysis. Along with the type of data, I also incorporated a number system to indicate when this data was generated in participants' ITP experience. Starr and Jacob joined the study in the fall semester, so their interviews were shifted. Below is a guide to how I used the notation to reference while reading:

Table 4.1

Guide to Current Notations

Data Type	Notation	Timing
Interviews	I1	June Interview (Tam, Azula, Madelia); August Interview (Starr & Jacob)
	I2	August Interview (Tam, Azula, Madelia); January Interview (Starr & Jacob)
	I3	January Interview (Tam, Azula, Madelia); May Interview (Starr & Jacob)
	I4	May Interview (Tam, Azula, & Madelia)
Reflections	R1	Summer Semester
	MRn	Reflection in summer about alternative teaching experience
	R2	Fall Semester
	R3	Spring Semester
Methods Course Observation	O1	Summer Semester
	O2	Fall Semester
	O3	Spring Semester
Lesson Plans	LP	

Challenging Ideologies

Ideologies are "systems of ideas and values that reflect and support the established order and manifest themselves in our everyday actions, decisions, and practices" (Brookfield, 2005, p. 67). Ideologies often appear as common sense, personally relevant, and desirable for the

majority. From a critical theory perspective, studying ideologies is "an inquiry into the ways in which people may come to invest in their own unhappiness" (Eagleton, 1991, p. xiii). Adults must learn how to critique ideologies in order to become aware of how ideologies influence their lives within systems. This learning task focuses on adult learners recognizing and then realizing the role an ideology has in their actions (Brookfield, 2005). Social justice and 3D science teaching and learning are classified as ideologies since a goal of the ITP program is for teacher candidates to view these ideas as common sense, personally relevant, and desirable for the majority of their students. Yet, for this to happen, teacher candidates must critique their held ideologies about science education and those presented in the ITP program. For this section, Jacob and Tam's experiences with challenging ideologies are highlighted due to their ability or inability to recognize and realize the role of these ideologies in their practice.

3D Science Teaching & Learning

The ideology of 3D science teaching and learning was new to all participants. Each was more familiar with being taught 'the' scientific method and participating in teacher-centered lessons. As Jacob described, "[3D] looks drastically different from what I experienced in my grade school… when I was in school, it was the scientific method, worksheets and all that stuff" (I2). Throughout the program, participants struggled with different aspects of 3D science teaching and learning. Jacob said, "I was so confused about what [crosscutting concepts] were and how they worked when we first learned about them, and it took quite a while for me to be convinced of their purpose and strength" (R3). Tam also found himself working to understand the ideology and how it fit in a classroom. He stated, "I tried my best to implement 3D learning, but I don't have a deep understanding of it" (O2). Jacob thought, "3D science teaching allows students to become well-rounded adults who understand how the world works while increasing

their curiosity and giving them tools to explore those curiosities. It is, in my opinion, the absolute best way to build scientific knowledge of content and skills necessary to be an informed person" (R2). Tam echoed Jacob's thoughts about teaching science through 3D. He "believed 3D approach is one of a few best way to teach science" (R3). Yet, Tam had difficulty recognizing how other beliefs about his students impacted his ability to implement 3D science teaching and learning. For instance, Tam explained he struggled to use 3D in the classroom because "I need an ideal environment. Not these kids...I need a prototype environment. Basically something I can test the theories on, as I say again, it will work in White school, where every single kid will have gone into the classroom with the same mindset that they want to learn science. Not the kids that want to survive in real life, whatever rough neighborhood they're in. It's not the same thing" (I2). Each participant actively critiqued the ideology by thinking about the benefits and challenges of implementing it in classrooms and school systems (Table 4.2).

Table 4.2

Participants Ideological Critique of 3D Science Teaching and Learning

Participant	Benefit	Challenge
Azula	"My kids aren't super familiar with the idea that there are these concepts that science revolves around. They are just like, 'Oh, yeah, that makes sense. Oh, that connects to something we did in August.' I'm like, 'Oh, my God, it sounds like we do it on purpose or something.' It's so funny to hear their epiphanies. And I love when they have them, because we're able to talk about them" (I3).	"Education that follows the 3D framework is almost impossible without the correct resources (The National Academies Press, 2012). Without the correct materials, students may be able to gain theoretical knowledge but are not able to fully understand the implications of the material they are learning" (MR3).
Madelia	"By including 3D learning in the classroom, it provides students with a more well-rounded and better education where they can think through the phenomenon and derive understanding by utilizing the 3D structure" (R2).	"I have noticed some things that might make its implementation in the classroom rather difficult for some teachers. Before taking this class, I had not heard of this framework… Incorporating this framework might also be difficult for some teachers who have been teaching for a long time and only use a particular method to teach their students" (R1).
Starr	"The affordances with 3D learning would be the experiences that it provides for students that might not be exposed to it at home. For instance, during the I AM STEM program, the students were able to build a solar fan and learned how it worked along with the ability to connect it with helping conserve natural resources and more. Without that experience some students would have missed out on that learning opportunity, like I did" (R1).	"It can be time-consuming when prepping for the lesson, explaining the terminology to the students, using the techniques, having students be responsible for their learning, making sure that the assessments are aligned with what it is that needs to be tested, and knowing what is expected of them (the culture/norm within the science community)" (R3).

Unlike other participants, this friction between aligning with 3D science teaching and learning and a deficit viewpoint of his students carried over into Tam's ability to implement this ideology as a way of practice for him.

All participants, including Tam, attempted to include 3D science teaching and learning into their practice. They each focused on different elements of the ideology in their practice at different times. For instance, in the fall semester, Jacob struggled with the science and engineering practices (SEP). As he said, "When I'm making my plans right now, it seems like every practice is like, obtain, evaluate and communicate or create an argument based on evidence. It's hard to get out of those two. Right now, it's hard for me to design a lesson where you like, don't do those, and you rely on the others" (I1). Azula recognized how her struggle with disciplinary core ideas was impacting her ability to implement 3D in her classroom. Azula expressed, "I'm scared with the core ideas part not because I don't understand how it applies to the 3D framework. But mostly, because I'm afraid that I won't have enough knowledge about those core ideas in order to implement all the other ideas around the 3D framework" (I2). While the other participants' concerns about using 3D in their practice related to their ability, Tam's concerns focused on other factors. When asked which area of 3D science teaching and learning he was least comfortable with, Tam responded, "Practice is definitely not okay for me, because the student can't practice. They don't have the material to practice. All we can do is probably cross cutting concepts" (I2). Tam discussed at length various reasons he was unable to implement 3D into his practice. They ranged from curriculum pacing to student apathy to lack of resources or funds. Yet, despite these reasons, Tam still attempted to use 3D in the classroom.

In order to understand how the ideology of 3D science teaching appeared in participants' practice, I analyzed their lesson plans and paid particular attention to the language of their

learning objectives. This is because ideologies are embedded in language (Fromm, 1968). Over the fall and spring semesters, all participants began to use more specific language in their learning objectives, indicating how the ideology of 3D science teaching and learning impacts their practice. Figure 4.1 shows the standards and learning objectives for a lesson Jacob planned in the fall. Here, the SEPs found in the curriculum standards match, or align, with the learning objectives Jacob constructed. Jacob does not explicitly state crosscutting concepts in this example of Jacob's thinking.

Figure 4.1

Standards and Learning Objectives for a Fall Lesson Developed by Jacob

Curriculum Standards GSE (Georgia Standards of Excellence) / National Curriculum Standards https://www.georgiastandards.org/Frameworks/Pages/BrowseFrameworks/Frameworks.aspx
S7L3. Obtain, evaluate, and communicate information to explain how organisms reproduce either sexually or asexually and transfer genetic information to determine the traits of their offspring. a. Construct an explanation supported with scientific evidence of the role of genes and chromosomes in the process of inheriting a specific trait. b. Develop and use a model to describe how asexual reproduction can result in offspring with identical genetic information while sexual reproduction results in genetic variation. (Clarification statement: Models could include, but are not limited to, the use of monohybrid Punnett squares to demonstrate the heritability of genes and the resulting genetic variation, identification of heterozygous and homozygous, and comparison of genotype vs. phenotype.)
ISTE Technology Standard https://www.iste.org/standards/for-students
1.3.a. Students plan and employ effective research strategies to locate information and other resources for their intellectual or creative pursuits.
Mode of Instruction Face to Face / Online Synchronous / Online Asynchronous / Hybrid
Learning Objective/Goal(s)
1. Students will obtain knowledge about how traits are found in the DNA, how DNA forms chromosomes, and what that means for meiosis and mitosis. - Identity: Students will understand that they are all a manifestation of their genetic traits. - Intellect: Students will learn basic information about what DNA, chromosomes, genes, and traits are. 2. Students will evaluate the different types of cell division. - Intellect: Students will gain knowledge about the processes of meiosis and mitosis. - Skills: Students will create a Venn Diagram to compare and contrast meiosis and mitosis. 3. Students will construct an explanation of how meiosis leads to genetic variation but mitosis does not. - Skills: Students will create an explanation about how meiosis and mitosis are different. - Joy: Students will write one cool or interesting thing that they learned during the lesson and include it in their ticket-out-the-door. - Criticality: Students will consider why some people are viewed as lesser despite having no control over their traits.

The usage of specific language in his learning objectives reflected Jacob's thinking and willingness to align with 3D in his practice. On the other hand, Tam's continual struggle with 3D science teaching and learning is evident in his learning objectives.

In the spring semester, Tam worked closely with his mentor teacher, Mr. Patel, to create several lessons based on the instructional strategy of Argument Drive Inquiry (ADI). Tam spoke specifically about his experience implementing 3D so completely in a lesson. He reflected, "The students asked questions, developed drawing (model), define methods, analyze data, and communicate results. Students use analyze data using the cross-cutting concept pattern to find any correlation and relationship between the variables. Finally, the students were explained how such concept and mathematics of projectile motion are applied to firearm battle sights, artillery computers, and computer programming to simulate interactive environment such as video games" (R3). Figure 4.2 shows the standards and learning objectives for this lesson.

Figure 4.2

Standards and Learning Objectives for a Spring Lesson Developed by Tam

PROJECTILE MOTION
Curriculum Standards GSE (Georgia Standards of Excellence) / National Curriculum Standards https://www.georgiastandards.org/Frameworks/Pages/BrowseFrameworks/Frameworks.aspx
SP1. Obtain, evaluate, and communicate information about the relationship between distance, displacement, speed, velocity, and acceleration as functions of time. **d. Analyze and interpret data of two-dimensional motion with constant acceleration.** **• Resolve position, velocity, or acceleration vectors into components (x and y, horizontal and vertical).** **• Add vectors graphically and mathematically by adding components.** **• Interpret problems to show that objects moving in two dimensions have independent motions along each coordinate axis.** **• Design an experiment to investigate the projectile motion of an object by collecting and analyzing data using kinematic equations.** **• Predict and describe how changes to initial conditions affect the resulting motion.** **• Calculate range and time in the air for a horizontally launched projectile.**
ISTE Technology Standard https://www.iste.org/standards/for-students
1c. Students use technology to seek feedback that informs and improves their practice and to demonstrate their learning in a variety of ways.
Mode of Instruction Face to Face / Online Synchronous / Online Asynchronous / Hybrid
Learning Objective/Goal(s)
Identities Students who are sport players will learn more about baseball, softball, golf, or basketball trajectories using simple algebra Students will look at these projectile motions in daily lives in a mathematical and analytical manner. **Skills** -Students will be able to calculate for how far a ball will land knowing the angle and its initial velocity. -Students will be able to calculate for the time a ball will be in the air knowing initial velocity, the angle, and gravitational acceleration. -Students will be able to craft a model to represent each problem as a tool for analysis. -Students will be able to solve hypothetical problems involving battleships and their big guns -Students can calculate for roughly where the baseball will land knowing the angle, initial velocity, and gravitational acceleration **Intellect** -Students can explain how computer games can simulate projectile motion by programming kinematic equations -Students can explain how old battleship can aim its guns and how elevated gun sights work -Students can explain how the motion of a baseball, basketball, ... can be influenced by the angle and the initial velocity. -Students can explain how shooting at an angle toward the sky during holiday celebration is a bad idea and irresponsible

Unlike Jacob's learning objectives, the verbiage of Tam's learning objectives somewhat aligns with the given standards. However, Tam does not include where students analyze and interpret data for this lesson. This practice is specific to the substandard of SP1 for this lesson. Because of this, Tam is attempting to use 3D in his lesson; however, he is working to make sense of what that looks like in his practice. Tam's amount of learning objectives should also be noted. The

lesson plan template called for three learning objectives. In this example, Tam has written 11 learning objectives. This could also speak to the work Tam is doing to make sense of critical science ideologies. Like Jacob, Tam has not included an explicit crosscutting concept in his learning objectives.

The journey of critiquing and working to align with the ideology of 3D science teaching and learning that Jacob and Tam both experienced represents the extremes of how participants worked to make sense of this ideology for themselves. The personal factors Jacob and Tam brought to the ITP program primed them for their depth of willingness to align with 3D science teaching and learning. Tam's background in physics allowed him to break away from the scientific method but hindered his understanding of the role culture plays in science. Jacob's variety of experience working with animals was also a touch point for aligning with 3D science teaching and learning. Their different contextual factors, such as their placement, held limitations and restraints towards what they viewed as possible. Tam's implementation of 3D science teaching and learning was challenged by the environment, lack of resources, and perceived apathy of his students. While Jacob's time teaching was limited in the fall, he was able to push back on what science teaching and learning looked like in school in the spring semester. Ultimately, each recognized and realized this ideology's role in their thinking and practice about teaching science.

Social Justice

Like the ideology of 3D science teaching and learning, social justice, particularly in education, was new to all participants. Teacher candidates were exposed to the ideology of social justice in the first class of their ITP program through two key texts: *We want to do more than survive: Abolitionist teaching and the pursuit of educational freedom* by Bettina Love (2019) and

Cultivating genius: An equity framework for culturally and historically responsive literacy by Gholdy Muhammad (2020). For Jacob, the texts "presented a world that's not my experience. It helped me work towards understanding what different students in my classroom experience" (O1). This ideology forced participants to recognize and question their thinking about race. After their first semester, and as they entered their placement, participants began to see how social justice appeared in the school setting. As Tam explained, "I have my personal bias. When I walk into the classroom, I do see colors… there's nobody that absolutely are not racist… you see a group of kids start acting rude, you start to generalize a whole group of people. You cannot escape it. Everybody has it… I just can't say it out loud" (I2). Others were forced to confront their privilege. Madelia confessed, "I'm White. I grew up in a sense privileged… I've been learning about how unfair [the system] is, how biased and oppressed… the discrimination that still exists, and I don't want to be a part of that anymore" (I2). As Jacob pointed out, confronting the role of Whiteness is an essential step in aligning with the ideology of social justice. He believed, "Acknowledging that there is a problem is a great first step. Next, it insists that white people, like myself, confront our own racism and privilege. It's vitally important that white people decenter whiteness in all classrooms, but especially classrooms that are made up of all white students taught by white teachers" (R2). Once participants were able to recognize how their understanding of race influenced their actions, they were better able to critique the ideology of social justice in the classroom.

As participants gained more knowledge and experiences in the classroom, their thinking about social justice in education changed. I asked participants, "What does social justice look like in the science classroom?" three times throughout their ITP program (Appendix C). Jacob and Starr have two responses since they did not join the study until the fall semester. In Table

4.3, Tam and Jacob's responses are presented. Their responses to this question reflected how they and other participants worked to critique the ideology of social justice within the context of science education.

Table 4.3

Jacob & Tam Responses to "What does social justice look like in the science classroom?"

Participant	June 2021	August 2021	January 2022
Jacob	Not interviewed	I mean, it's like social justice anywhere else. You have to talk about tough topics you can't ignore things that are going on, you can't ignore what's happening, like outside of the school… you can't expect kids to ignore those things. You have to know who you're teaching… I think that having an adult figure talk positively about them when most of the time they're viewed down upon is a very new experience for them… even having one teacher who recognizes differences… I think that that can really have a big effect on kids… then kids don't see themselves in [science]… you're not going to actively tell them that it's not for them.	I think it can look a lot of different ways. The way that I typically do it is: introduction... Because when I turned in my first lesson plan last semester… it was in the outro. I was relating it a social justice thing and be like, 'Alright, have a good day.' They didn't have time think about it or do anything with it. It just seemed kind of like an afterthought… I think incorporating it into lessons depending on what you're doing or starting off the class like that. Some topics are much easier to do it than others. When you're talking about organelles in cells that's not super easy to relate to social justice… Somethings it's much easier to make relevant to social justice than others. Sometimes with stuff I feel like it's a stretch and the kids are like, 'What is he doing? That's weird.'

Participant	June 2021	August 2021	January 2022
Tam	Why I see in science class is teachers, they don't care about their student being successful or not. They just like, 'Oh, this is what you need to survive. Just pass this test and get out of here. I don't care what you're gonna do. You can stay out in the street, but at least you pass my class.' So that's the mindset that everybody do when they go to class you don't understand them, you just want to pass a test... that's why in the science classroom in that Panther Park High School, nobody's going to be anything successful. Because they just come in to survive. They don't care about a science…	I would say it was very hard to find social justice in science. But in my title one school, I can see that these kids, they're not as equal as the one in in White school. They don't have the same education. The only way we can deliver social justice is to have them to do the same thing as people are doing in another in another school… Whatever material they have in other schools, we need to have the same thing… We cannot push good teachers into this class and expect them to deal with this kids for nothing… Meanwhile, we here...With low income kids, mostly African American, again, are doing nothing in the classroom… We're missing the power of getting to know...get them get learned. We're missing that part. You see what I'm talking about. They're just survive...surviving	Social justice, I say it's pretty...everybody's equal in my classroom. I don't care if you're gay, I don't care if you're lesbian, I don't care if you're black, brown, pink, yellow, I don't care who you are, as long as you do well, in physics, as long as you ready to have a mindset that you want to contribute something to society to this country. You're my kind of people. Don't just go walk into my classroom and ask me for a passing grade. I don't want that to happen, because that's not how you do...that's not how you do social justice. That's bring you even a worse image of yourself and your community that you are not really trying hard. So justice is when everybody got an equal opportunity in my classroom to be successful.

All participants sought a way to connect social justice to the content they taught. Participants worked closely with the Historical Responsive Literacy (HRL) Framework (Muhammad, 2020). The element of identity from the framework was how Tam attempted to make learning science relevant for his students. For him, "by discussing [students] own daily observations of the phenomenon, the students felt that the lesson is relevant and is attracting to understand. They were able to connect themselves to the idea in lessons and perform well" (R2). Still, Tam found using identity "extremely difficult because teachers must find a way to make the lessons connected to the students' lives and create their own identity in the classroom" (R3). Tam also spoke to the challenges of centering social justice in the science classroom. He thought, "Social justice, [on] paper is pretty. When you implement it in real life, in teachers, especially when they under stress or when they in real life. And they don't know how to react. They don't know how to implement it. In the lesson, they probably they just got ignored (I1)." Jacob viewed using social justice in his teaching as empowering for students. As he said, "Making [learning] anti-racist, social justice, and including that aspect of it, and just making students understand, it is an option for them… for all of them, because it's not just science, it's everything, …then they would have the confidence or understanding that they could do it" (I2). Yet, Jacob struggled to ensure that usage of social justice in lessons was age-appropriate. He explained, "It was also very uncomfortable for me at first. I think a lot of it had to do with them just being so young…introducing things to them and then just not really having the full grasp of the world yet" (I3). Each participant actively critiqued the ideology by thinking about the benefits and challenges of implementing it in classrooms and school systems (Table 4.4).

Table 4.4

Participants Ideological Critique of Social Justice

Participant	Benefit	Challenge
Azula	"Abolitionism is rooted in treating our students like the humans they deserve to be treated as… Over my coursework thus far, I have established that intertwining abolitionism and genius within my classroom requires social-emotional learning and vulnerability on my end" (R3).	"Not every curriculum area is easily connected to social justice aspects in a way where it actually matters. It's hard for me. I've seen that constantly over and over again. I make the connections wherever I can, but it's really hard in some aspects…some days where we're focusing on details…if we're working on Hardy Weinberg… it's hard for me to make that social justice connection" (I4).
Madelia	"I want to also incorporate the HRL framework outlined by Muhammad (2020), and in particular, focus on identity because I feel like a lot of students need to see themselves in the curriculum or be inspired by someone who they resonate with" (R2).	"I'm still struggling with the criticality piece simply because of the whole critical race theory thing that's going on right now and how people are, like very taboo about it, even though it's necessary for kids to know and understand what's going on around them. I'm just not sure how to approach it simply because of that part right there" (I2).
Starr	"Most importantly, I would show [students] respect and that I will go the extra mile to relate to them. We are not all the same, but we still should be able to sympathize and/or empathize with each other. Also, making sure that my (their) culture (clothing, hair, etc.) is recognized and not overlooked or shunned. Therefore, showing them how to be proud of who they are and where they come from by showing them that we (including teachers) are human just like them" (R3).	"The idea of "working in solidarity with communities of color to eradicate injustice in and outside of school" (Love, 2019, p. 2) is going to be a challenge" (R2).

In order to understand how the ideology of social justice appeared in participants' practice, I analyzed their field performance observations conducted by their university

supervisor, Mrs. Reid. I paid particular attention to the criticality indicator from the observation rubric (Figure 4.3). This indicator most aligns with the goal and objective of the HRL framework and demonstrates how the ideology of social justice showed up in participants' actions.

Figure 4.3

The Criticality Indicator from the Observation of Field Performance Rubric

INDICATOR	*Advanced*	*Proficient*	*Developing*	*Insufficient*
PROFESSIONAL KNOWLEDGE				
5-PK **Criticality:** **Interrogates the sociocultural context of the content using local, national, or global real-world issues connected to social justice and equity to foster authentic dialogue, address injustices, and realize social change.**	Interrogates the sociocultural context of the content using local, national, or global real-world issues connected to social justice and/or equity to foster authentic dialogue, deliberation, or discussion, **AND** address injustices **OR** realize social change.	Uses local, national, or global real-world issues connected to social justice and/or equity to foster authentic dialogue, deliberation, or discussion, **AND** address injustices.	Uses local, national, or global real-world issues connected to social justice **AND/OR** equity to foster authentic dialogue, deliberation, **OR** discussion.	Does not use local, national, or global real-world issues connected to social justice **AND/OR** equity to foster authentic dialogue, deliberation, **OR** discussion.

Overall, participants demonstrated growth within this indicator. By the end of the spring semester, participants scored either proficient or advanced in this indicator. In Table 4.5, Jacob's consistent growth is an exception. Most participants oscillated in their score, similar to Tam. This further demonstrates participants' struggle to implement social justice into their lessons in a way that worked for them.

Table 4.5

Scoring on Criticality Indicator for Observations Conducted by Mrs. Reid

Participant	Fall 1	Fall 2	Spring 1	Spring 2	Spring 3
Azula	Developing	Developing	Developing	Advanced	Proficient
Jacob	Developing	Proficient	Proficient	Advanced	Advanced
Madelia	Advanced	Advanced	Advanced	Advanced	Proficient
Starr	Developing	Developing	Advanced	Developing	Advanced
Tam	Developing	Proficient	Developing	Proficient	Advanced

Many factors influenced participants' willingness to include social justice in their practice. A major concern across all participants was the political climate and conversations around critical race theory in education. During their time in the ITP program, the state where the study took place passed a bill that banned teaching specific divisive concepts, including race. The state's governor later signed the bill into law (Laughland, 2022). Several expressed concerns about "getting in trouble" or not knowing how to best incorporate social justice into the classroom where they felt safe. All participants struggled to incorporate the elements from the HRL framework of joy, criticality, and identity into their lessons. Tam explained he often did not use criticality because "I don't really know what I do as appropriate...was not. So I'm just leaving it out… I won't do criticality" (I4). From their lesson plans, participants consistently used the elements of skills and intellect accurately. The element used the least across all participants was joy. The challenge participants encountered with implementing joy was summed up by Jacob when he recalled "In the lesson plans that I turned in this week, it was like, 'Oh, the students will find joy in sharing what they learned with their peers.' I don't know if that's going to genuinely bring them joy, or if that's just me, hoping that's what happens. It's the only thing that I can think of, so I definitely struggle with joy. I try to make lessons as fun as possible. But I know having lessons be fun isn't the whole point of joy" (I3). Participants recognized the ongoing process of incorporating social justice into their practice and realized its role in teaching all students science.

Link to TCSR

Contextual Factors

Participants encountered various contextual factors during the ITP program; however, one that varied and impacted them the most was their placement school for practicum. Each

participant found themselves navigating a school, department, and classroom that informed how they could enact the ideologies of the ITP program. For instance, Jacob was the only White man in the entire middle school he was placed in. This made it “uncomfortable for me as an authoritative White figure to talk about social justice with a bunch of little Black kids who don't probably understand the scope of how things truly are. I've been trying it and it's been fun. I definitely think it's like a necessary part of any class” (I2). Instead of using his Whiteness as a reason to limit his usage of social justice, Jacob decided to view it as an asset. For example, Jacob chose to use skin color to teach about different systems in the body. As Jacob explained, “Every single student in every single one of my classes is Black. So, for identity I was like, ‘Why do we have different skin colors?’ I was gonna leverage the fact that I'm White. By bringing attention to it, I think that is more than most teachers would do. They would shy away from it and get uncomfortable. I was going to be like, ‘What color your bones? What color are my bones? What color are your muscles? What color my muscles? What color is your skin? What color is my skin?’ And then be like, ‘It's a unique organ’” (I1). Jacob recognized how using social justice in his lessons revealed his thinking towards how he wanted to teach all his students.

In contrast, Tam found his placement limiting in how he could teach science. He wanted his students to do “hands on stuff, I can't do that. I don't have the money to do it. Sure I can buy the stuff and make demonstration for them in the classroom, but...they don't pay me. I pay them to go and student teaching. It's not fair for me to try to implement 3D teaching into because the school not willing to pay to for me to do it (I2).” During the fall semester, Tam’s placement changed. This experience reinforced his challenges when trying to implement the ideologies presented in the ITP program. As Tam described it, “So when I switched from Panther Park High

School into Mustang High School, I saw a very, very distinct change... it went from already a prison to another even worse prison. It's just really you go into Mustang High School and you feel really depressed" (I3). Here, Tam also found issues with the physical classroom. He expressed, "My physics classroom in [Mustang] High wasn't a lab-oriented room but rather a traditional lecture type of classroom where the students are closely packed and seated in desks facing the board that is not even a board anymore but an annoying and massive, but also at the same time, small touch board" (R3). While Tam was able to recognize the ideology of 3D science teaching and learning, the limitations allowed Tam to find reasons to resist putting the ideology into action. These contextual factors worked together with the personal factors participants brought to their placements to inform their practicum experience.

Personal Factors

Each participant brought their prior learning experiences and personal histories to the ITP program and their placements. These impacted how participants related to and engaged with the ideologies of 3D teaching and learning and social justice. Jacob entered the program already open to the ideologies presented in the ITP program. Jacob stated, "So [the program] was much more like, equity, Justice focused... at least equal parts of that to teaching, which was awesome, because I didn't know that but that aligns with my feelings and beliefs and the reasons that I did this in the first place" (I3). Whereas, Tam's experience of being an immigrant to the United States made it difficult for him to execute the HRL framework. He found "these kids are really hard to get along. Because I, myself and them, we don't have the same culture. So we are completely different. I was not born here. So I don't understand what your childhood look like. What do you guys see when you guys was young? I don't know, how can I connect you guys

personally" (I4). Even with these different experiences, a common thought arose from all participants.

Each participant had unique experiences within their personal and contextual factors that impacted their ability to challenge the ideologies of 3D science teaching and social justice. Yet, a common way of thinking emerged; each participant combined the two above ideologies into one: critical science ideology. Critical science ideology grounds the practice of instructing students in science using the elements of 3D science teaching and learning while centering and cultivating their genius. To do this, teachers must recognize "the brilliance, intellect, ability, cleverness, and artistry that have been flowing through [students] minds and spirits across generations" (Muhammad, 2020, p. 14), as well as their own genius. Depending on their understanding of each ideology, participants began to think of 3D science teaching and learning and social justice as critical science ideology either in the summer or fall semester of the ITP program (Table 4.6). For all participants, this emerged in response to the reflection question, "How can you cultivate a genius in your classroom while being an abolitionist teacher?"

Table 4.6

First Emergence of Critical Science Ideology

Participants	1st Mention of CSI	Evidence
Azula	Summer 2021 Reflection Response	As future educators of the generations of people that will develop our worlds, **it is our responsibility to provide a historically relevant and considerate view of science education**
Jacob	Summer 2021 Reflection Response	**I think the main way I will be able to cultivate genius is through 3-D teaching**. This concept, if implemented correctly, will make it nearly impossible to not be an abolitionist teacher
Madelia	Summer 2021 Reflection Response	**To cultivate genius in my classroom I want to ensure that I am using crosscutting concepts** that can help students gain a deeper understanding of the subject matter, promote critical thinking of injustices that can be supported by the data in science, and encourage students to learn from each other instead of just depending on themselves.
Starr	Fall 2021 Reflection Response	In conclusion, Knowledge is Power! Therefore, **3D teaching and learning would be the tool to help create that knowledge. "If students know themselves, they are engaged with the confidence to learn the skills**. If they have the skills, they can learn knowledge and critique the knowledge" (Muhammad, 2020, p. 60). **They would be able to do so by using "lenses on phenomena, CCCs provide different perspectives for thinking** about how and why phenomena occur" (Nordine and Lee, 2021, p.11).
Tam	Fall 2021 Reflection Response	Last week, we were discussing inertia, I found that many students already had the existing knowledge of the basic concept …**So, by discussing their own daily observations of the phenomenon, the students felt that the lesson is relevant and is attracting to understand.** They were able to connect themselves to the idea in lessons and perform well.

Participants saw these two ideologies as tools for connecting to their students and making content relatable to their lives. To them, it had become common sense for participants to teach science through these combined ideologies. By learning about these two approaches to

instruction simultaneously, participants acknowledged the overlap in what each ideology holds at its core: cultivating all students to engage in learning. Yet, the way teacher candidates engaged with the critical science ideology was influenced by the depth of participation in the adult learning tasks and their personal and contextual factors. The following section examines how participants contested hegemony within their thinking and practice while considering their personal and contextual factors.

Contesting Hegemony

Hegemony is a process that causes individuals to be oppressed through their own beliefs and practices while elevating those with power (Brookfield, 2005; Marx & Engels, 1970; West, 1982). Hegemony often appears through micro-decisions made during the day (Brookfield, 2005). To code for hegemony, I looked for the decisions participants made during the program related to their practice. Their decisions around practice reveal their thinking about their role, students, learning, and the ideologies of social justice and 3D science teaching and learning. The adult learning task of contesting hegemony outlined by Brookfield (2005) focuses on thinking critically about power, control, and learning to recognize one's class position and true political interests. This learning task demonstrated how participants questioned their roles and actions in the classroom to contest the status quo in science teaching. In this section, I will highlight the experiences of Madelia and Azula, who were selected due to how they contested hegemony within themselves and the system.

Questioning

Throughout their time in the ITP program, each participant questioned either their role in the classroom, how their life experiences impacted how they showed up in the classroom, and/or different policies and trends they noticed at their placement schools. Once participants began to

question, a shift in their actions tended to follow. For Madelia, she first began questioning what it meant for her as a White woman to teach historically underserved students. She was aware of "the whole White savior complex, and I don't want to fall into that… I'm not trying to be anybody's savior. I just am trying to be a person to make a difference in someone's life… I'm kind of struggling with that identity as to what can I actually do to make a difference for these kids, but not fall into that White savior complex" (I3). Meanwhile, Azula began to question practices in the school regarding the racial make-up of the classes she taught. Since she taught honors and gifted biology, students were placed into her classes; yet, "the amount of Black students [she had] is not nearly representative of the amount of Black students" (I2) at Palomino High School. Azula was prompted to seek information about her placement school from an assignment, the Ecological Equity Audit. This information led Azula to "pull out a lot of things that [were] unseen" (I2) to her, such as statistics focused on disciplinary actions, socioeconomic status, racial demographics, and accommodations for students in her district and placement school. The type of questioning Azula and Madelia participated in, as well as the other participants, was reflected in their practice.

Participants were asked in their final interview, "What was your most successful lesson this year?" Based on their responses (see Appendix D), I was able to analyze their lessons for decisions in how they chose to teach this lesson. All participants chose to use elements of the HRL framework in their lessons. Skills, intellect, and identity appeared in all the lessons, while criticality and/or joy appeared in all participants' lessons, with the exception of Tam's. Participants also chose to explicitly include elements of 3D science teaching and learning in their lesson, except for Madelia (Table 4.7). This may be because she selected a review lesson as her most successful lesson. Jacob was the only participant to have consistency across his standards,

learning objectives, and activity with both the HRL and 3D science teaching and learning. Starr did include all elements of 3D science teaching in her learning objective for her most successful lesson, but did not expand her selected science and engineering practice into the lesson. These decisions reflect participants' questioning of how they teach science and how they can meet the needs of all their students. By including elements of the HRL framework, participants took a political stance that positioned social justice as a central part of their lessons. With the inclusion of 3D science teaching and learning, participants thought critically and questioned how science is taught. They all pushed back on the hegemony of their mentor teachers' classrooms by including both social justice and 3D science teaching and learning in their lessons.

Table 4.7

Azula and Madelia Questioning Hegemony through Practice

Participant	Response	Lesson Standards	Learning Objectives	Alignment of Learning Objectives & Activities
Azula	"It was actually a modeling activity. This was at the start of the year when we were learning about DNA and RNA… in order for my students to better grasp what DNA looks like, because it's so hard for them to understand."	**SB1. Students will analyze the nature of the relationships between structures and functions in living cells.** **SB2. Obtain, evaluate, and communicate information to analyze how genetic information is expressed in cells.**	**Identities**: Students will also be able to use their own creative identities to participate in some of the activities. **Skills**: They will be able to explore what DNA looks like, where it is found in the cell, and why it is important to life as we know it. **Intellect**: They will have to recall the processes of mitosis and meiosis and understand what role DNA plays in both. **Criticality**: Guiding questions in the conclusion include those about genetic complications and what disadvantages they may cause. **Joy:** Students will be able to partake in a fun introduction activity that allows them to stray from the norms of the classroom.	In her lesson plan, Azula noted how her opening activity of using a social media trend called "wrong answers only" aligned with her learning objectives: "I would like to use this aspect of the lesson plan to implement Identity and Joy, as students will be able to put a personal twist on their answers while also having fun and being silly. Students will be using intellect in this section in order to provide answers to the discussion questions, as their learning of DNA and its importance will be sparked." Students met the skills learning objective in the body of the lesson by completing the strawberry DNA lab. She also identified the single question in her closing that addressed criticality: "If someone's DNA does not look the way it's supposed to or is not in the right place, what can that affect? This question will address criticality"

Participant	Response	Lesson Standards	Learning Objectives	Alignment of Learning Objectives & Activities
Madelia	"The trash kickball, I did review with the kids. They really, really liked that and [Starr] gave me that idea… I set it up in a way to where everybody could participate."	**SC1. Obtain, evaluate, and communicate information about the use of the modern atomic theory and periodic law to explain the characteristics of atoms and elements.**	**Identity**: Students will be able to use their knowledge about the curriculum and athleticism to help them play together as a team to win. **Skills**: Applying knowledge and thinking abilities to answer the questions. Intrapersonal skills will be utilized and enhanced as the students work together. **Intellect**: Students will be using their knowledge about the curriculum to answer review questions in preparation for their test the next day. **Criticality**: None for this lesson. **Joy**: Playing a game together and being about to compete for some donuts.	Madelia chose to introduce the review activity by talking about March Madness. Madelia identified "trashketball" as part of her introduction and body for the test review. This activity required students to work as a team to answer review questions. When students get the questions right, one of their team members shot a paper ball into a trash can for additional points. The team with the most points won a donut.

Contesting

Participants found themselves often contesting the norm in their placement schools or in their own thinking. Madelia challenged the common narrative from science teachers in her building that limited funding and time kept them from altering how they taught their students. While she understood that "if the teacher only has a limited supply of resources, it may prove to be difficult to provide [3D learning] experiences to students" (R3), she contested that this type of science teaching and learning is still possible. Madelia found her response within the HRL framework. For her, "In order to help dismantle some of the inequities that are prevalent in many schools, Historically Responsive Literacy (HRL) outlined by Dr. Muhammad (2020) can provide an additional way for teachers to include doing science; through argument… While physical resources may be difficult to obtain for these school districts, internet access and some savvy searching can yield an effective argumentative experience for students which can help to pursue the scientific enterprise" (R3). In contesting the appeal of status quo science teaching, Madelia combined social justice ideologies and 3D science teaching and learning. Azula used social justice to focus on disputing her thinking related to her students.

In her words, "I had a group of girls sitting together, and they were being relatively loud. I looked at them, and I was like, 'Do I think that they're being rambunctious because these are three Black girls sitting together? Or are they actually being disruptive? And I'm like, 'If this was anyone else, would I actually say something to them?' I thought about it. No, I wouldn't say something to them, because they're not disrupting the entire classroom. They're just being a little loud'" (I2). Azula recognized she was experiencing "a lot of undermining my brain from things that I learned" in the past (I2). Her experience demonstrates how participants evolved from

challenging ideologies to challenging everyday actions. Madelia and Azula elevated their experience with contesting hegemony by putting their thoughts into action within their practice.

While all participants contested hegemony by thinking criticality about power and control, they did not all enact their thinking into their practice. Madelia, Azula, and Jacob all pushed back on the norms of science teaching (Table 4.8), while Starr and Tam did not. Depending on their placement, the ways Azula, Madelia, and Jacob were able to challenge hegemony varied. Azula's science department in her placement was restrictive and required all biology teachers to cover the same material in the same way. Because of this, she was forced to contest hegemony in small but meaningful ways, such as altering how students took notes. By contrast, Madelia and Jacob had much more freedom in planning and enacting their lessons. Both of them worked to implement critical science ideology into their lessons and faced a type of pushback. In Madelia's case, she developed and taught a lesson about graphs in several different science classrooms. After seeing her lesson in action, several teachers who initially challenged her thinking began to appreciate how Madelia connected graphs to students' lives. Jacob, on the other hand, experienced praise from the other science teachers for his lessons, but when he shared lessons, the other teachers would remove the instructional strategies related to critical science ideology. As Jacob explains, "They took the lab station lesson that I did, and redid it back, like reverted it a little bit to like non 3D… [The other science teacher] wasn't sure what to do" (I3). Azula, Madelia, and Jacob each contested how science was taught in their placement through their actions and had their critical thinking about science teaching validated.

Table 4.8

Participants' Contesting Hegemony in their Practice

Participant	Initial Quote	Artifact	Reflective Quote
Azula	"My mentor does guided notes. She'll use a printout with blanks, and she'll talk through notes and fill out things via doc cam. I've noticed that a lot of students just stop listening… I wanted to take a different approach to notes and be like, 'Hey, I'm just going to lecture you and you're going to write down what you think is important.' I still gave them the guided notes, but I made sure not to explicitly say any of those things where they could fill in blanks. I want them to fill them out by themselves" (I4).	"Students will practice taking notes and being part of discussion in class. They will also be able to practice their research strategies by looking up organisms for their food chains. Students will specifically focus on the crosscutting concept of systems and system models when talking about food chains and food webs" (LP).	"And [the students] hated it. They were so mad at me and I laughed so hard. I looked at all of their notes, and they were beautiful. I was like, 'You got all of the material that you needed. Why are you freaking out?' I think it was just a matter of them having the creativity and the independence to self-assess and be their own person in the classroom, rather than just being grouped and it being like, 'Hey, everyone's going to do the same thing today'" (I4).

Participant	Initial Quote	Artifact	Reflective Quote
Jacob	"You know the cheeks lab where you scrape your cheeks? I did that the other day. All the teachers in seventh grade were like, 'Oh my God, that's so crazy.' I was like, 'I Googled cell lab, and this was the first thing that popped up.' It's not groundbreaking. It's not crazy, but all they ever do is PowerPoints, worksheets, and gizmos. The most basic stuff blows their minds. They're like, 'Oh, give me that. Let me get that.' I don't know if it's because they don't want to do the work, or they just don't know… It feels weird that I'm still learning, and what I'm producing is groundbreaking to them" (I2).	"Even if you have a kind, smart teacher, if they play by the rules and the norms of our education, they will most likely not reach every student in a way that allows them to cultivate their genius. The rules and norms that I'm mentioning may result in a teacher reaching a lot or most of their students, but if a teacher isn't interested in reaching every student, then they need to find another profession" (R3).	"[The science teachers] had never even heard of [3D teaching]. I was explaining it to them. And they're like, 'Oh, okay, cool. Yeah, that's great.' They took the lab station lesson that I did, and redid it back, like reverted it a little bit to like non 3D… he wasn't sure what to do. I couldn't give him a whole rundown on like, cross cutting concepts, because that took me six months to understand" (I3).

Participant	Initial Quote	Artifact	Reflective Quote
Madelia	"The goal would be to show them [hip hop] information, read the graphs, and explain what we're getting from reading graphs, like, what kind of story are they trying to tell? And then telling them, 'Okay, now you guys are going to make your own graph. Find whatever musical artists you want to do and pick information that you're going to graph.'…And once they get on something they're interested in, then flipping it and being like, 'Well, how does this apply to science?' And then slipping the science into there" (I2).	"The instructor can explain that graphs help tell a story about information just as the students just did with their research and the article they read. Hip hop has been used by African American communities to express themselves and speak out against oppressions they have faced. Both science and hip hop are beautiful ways that people can express themselves and support ideas and tell a story of what is happening in the world*" (LP). *Emphasis by Madelia	"I've done it in like a couple of different classes. And the teacher who's next door, he was doing a heating curve. And he's like, 'Oh, can you do your graph lesson plan with them the day before? And then I'll do the heating curve for the next day.' And he's like, 'That went really well. That kid, he never talks, and he was talking the whole time. They were really engaged.' This guy he's kind of like, he kind of, he doesn't like, put me down… But he kind of dismisses some of the stuff I say, because he's been teaching for like five years? But anyway, it's just kind of like, 'See? It works.' I did a great job" (I3).

Link to TCSR

Contextual Factors

The nature of the ITP program encouraged participants to contest hegemony. In particular, the texts required for students to engage with supported their ability to recognize, reflect, and challenge hegemony. Madelia was impacted by "the books that we've read. Love in particular, is really uncomfortable to read, because, 'Wow, this is so bad'. All of this is relatively recent, and that makes me uncomfortable… it makes me want to do something about it" (I1). Participants' placements allowed them to apply their critical thinking skills about the education system (broad cultural context) and how hegemony maintains the status quo. For example, Azula recognized how the education system worked to diminish students' genius continually. For her, "the most physical way I have been able to see the importance of [abolitionist teaching] is through the lack of diversity in my school district, the lack of fairness in the disciplinary setting, and the amount of work that needs to be done in order to be a truly pluralistic and relevant community" (R2). Participants also observed how individual schools work to maintain hegemony. For instance, Madelia quickly began to think critically about how power and control were used in her placement to consistently oppress students. She "already noticed some differences in the way I approach things that I observe are unjust. For example, when a student recently got in trouble… and who has a history of being in trouble, my immediate reaction was 'Is she getting the help she needs to do better?' instead of saying 'She was getting the punishment she deserves'" (R2). Specific texts, reviews of their school districts, and observations of their placement schools supported participants in contesting the hegemony they experienced daily. While the participants' individual experiences were different in contesting

hegemony, they each craved the same thing: mentor teachers who contested hegemony by engaging in social justice.

When participants discussed their mentor teachers, all admitted they never observed a 3D science teaching and learning lesson or a lesson intentionally including social justice (Table 4.9). While each had positive personal relationships with their mentor teachers, they struggled with not seeing elements of social justice in their placement classrooms.

Table 4.9

Participants' Observations of their Mentor Teachers

Participant	Participant's Description of Mentor Teacher	Observed Social Justice Teaching
Azula	"My mentor teacher doesn't necessarily plan in advance very often… But it's a little bit of a struggle for me to stay organized only because she is a little bit everywhere, a lot of the time. So she'll be like, 'Okay, we're doing this on Friday.' Then I'll come in on Friday, and we're doing something totally different. …being mentally prepared for class has been a little bit of an issue" (I2).	"I think that it's not necessarily always super difficult to engage the HRL into the classroom… I feel like my mentor teacher doesn't necessarily take the opportunity to do so" (I2).
Jacob	"My mentor teacher had a reputation of you can do whatever you want in here and get away with it. Because she would put a video up on the board, give them a worksheet and, you know, start shopping on Amazon, and you wouldn't hear from her for the rest of the class" (I3)	Did you ever get to see a lesson from like, either mentor teacher or other teachers in the building that incorporated aspects of social justice? **Jacob** "They didn't do. I never saw anybody do that, like I… never once" (I3).

Participant	Participant's Description of Mentor Teacher	Observed Social Justice Teaching

Madelia	"She very much does things her way. You know, and I love her to pieces. It's just sometimes, you know, she calls [social justice] fluff… Seems like do you have to do all the fluffy stuff" (I3).	"I don't think she did any of [3D and social justice], like on purpose. Something would happen in the school, right? And she'd be like, 'Okay, guys, we're gonna be talking about this.' She would talk about COVID. And we would talk about how the majority of Black Americans are being disproportionately affected by it. We talked about that a little bit, but she didn't intend on that kind of lesson to begin with. It just kind of happened that way" (I4).
Starr	"I'm definitely enjoying it and happy that I ended up with him because I feel like he takes me completely out of my comfort zone. He's like, 'Okay, so what are we doing what you want to do? These are the options, but we ain't got to do them, or, you know, choose between these.' I was expecting the more, 'Okay, you do that.' …He's like, 'Raise your art. You teach it the way that you want to… how you're gonna be comfortable'" (I3).	Did you get to ever see like your mentor teacher or any other teachers in the building teach a lesson that had like social justice aspects involved in it? **Starr** "No" (I3).
Tam	"He doesn't really talk much with other people in his department. So, we're living in a room that really isolated, a physics classroom that is just small" (I3).	"My mentor teacher couldn't do it. He couldn't really make them feel a little bit connected to the lessons. So he basically just, 'Okay, this is...you guys are going to have to answer the SEO [social emotional objectives] question in 10 minutes," and then move on. Nobody remember anything about the SEO stuff. It's more like he's just trying to fulfill the requirements" (I4).

Azula was often frustrated because she was unable to prepare instructional strategies that contested hegemony due to her mentor teacher's lack of planning. Madelia found her mentor

teacher was dismissive of including social justice in the classroom by referring to it as “fluff” (I3). Starr was the only participant who appeared to have a positive view of their mentor teacher’s instruction. Yet, she still wanted to see a lesson taught that was grounded in critical science ideology. Starr wondered, “How far do you go? …How far in depth do you go with teaching that kind of stuff? I think it would have helped to see an example” (I3). While Madelia wanted “to watch someone else teach using Dr. Muhammad’s HILL model of lesson planning (Muhammad, 2020)... I think doing this would help me better translate my lesson plans into teaching along with picking up additional teaching methods and styles” (MR2). Overall, all participants agreed they did not see a lesson that purposely included social justice during their placement.

Personal Factors

Participants also drew upon their past learning experiences to contest how educators teach science. For Azula, her experience in college with learning science made her realize how important knowing how to ask questions was to her. As she tells it, “It was really frustrating for me, because I had a huge love for science in high school...When I got to college, I thought that I was stupid, but I wasn't stupid. My teachers weren't doing the things that I needed them to do in order for me to succeed as a student. It was difficult for me to ask too, because I didn't know what to ask or how to ask” (I1). Azula’s experiences in college with science professors led her to value building relationships with her students. Whereas Madelia realized how impactful it would have been for teachers to connect lessons to her culture. She told her methods course, “My background is Greek. It would have been really cool if my teachers had mentioned that or included it” (O1). All participants drew upon their experiences as students to inform how they decided to instruct, relate, and interact with their students. This appeared differently for each participant. For instance, Starr met a professor in college whose tests “were more like, how we're

trying to teach students now. It was more like application. Because at that time…you go on your whole life doing multiple choice questions, and it's just almost like regurgitation. Then you get to a class, and it's like, now you have to apply it. That's a whole ‘nother ballgame. That year, it actually helped me, turn around how I study. Don't just do it, because that's what you’re told, ask why” (I1). This personal experience supported Starr’s desire and conviction to contest hegemony and implement 3D science teaching and learning into her lessons. Tam’s decision to push back on his district’s physics curriculum was directly influenced by his experiences in the physics classroom. As he said, “Because it's happened to me in high school. I studied dumbed down physics, I go into college...I see real physics and I'm like...all these people from high income levels schools ...they are more advanced than me” (I2). Like the other participants, Jacob’s science learning experiences were examples of what he did not want to do as a teacher. In his time as a student, “We rarely ever did any experiments or anything like that. I feel like if I didn't already enjoy science, then I would have never turned to it because of a class… Nothing that I did in science in K-12 stuck with me… it was just giving us information. That's not what is going to stick with kids in the long run” (I1). Overall, participants found they needed to contest hegemony to become the teachers they envisioned themselves as. Once this occurred, participants could unmask power around and within themselves.

Unmasking Power

Michel Foucault (1982) defines power as more than interactions in relationships; it is how certain actions modify others. The adult learning task of unmasking power occurs when adults recognize they are agents of power, constantly channeling disciplinary power (Foucault, 1982). Still, they also possess the capacity to undermine dominant power relations (Brookfield, 2005). While analyzing participants’ data, I looked for when they recognized power and how

they could exert it in their placement context. This learning task demonstrated how participants came to view themselves and others, along with action, or lack thereof, through the ideologies of 3D science teaching and learning and social justice. In this section, I will highlight the experiences of Starr and Madelia because their journeys demonstrate how teacher candidates interact with power from the classroom (Starr) to a broad cultural (Madelia) context.

Recognizing

Each participant had experiences throughout the program where they recognized the power and authority stakeholders in the education system hold. In particular, participants found themselves navigating repressive and liberatory power (Foucault, 1982). Repressive power constrains and coerces individuals to its will. Liberatory power animates and activates others to take control of their lives, often in work that counters hegemony (Brookfield, 2005). Both forms of power are present at all times (Foucault, 1982). Madelia recognized how the educational system uses repressive power to maintain the status quo. As she said, “I can also see how the school system is failing [Black and Brown students]… if the information that they are forced to learn is not interesting to them…and if the system that is supposed to support and nurture them is doing the opposite, then they cannot thrive” (R2). Other participants recognized specific ways their roles in schools and the program could carry repressive power. Jacob saw how “when teacher’s gossip or say anything negative about [students] at any point, they reinforce the notion that some students can be left behind” (R2). Azula recognized and experienced repressive power through the design of the ITP program. When discussing how teacher candidates are unpaid while in practicum, she stated, “That was always really hard to swallow. It's definitely hard… I don't have an agenda against the program. I get it. It just sucks the way that it is. It's the system. It's the way that it's set up” (I3).

On the other hand, Starr experienced liberatory power through her alternative teaching assignments during the summer methods course. Starr explained, “I feel as though the students have helped create my Black joy. I am proud and excited to be able to use these empowering and helpful resources for my students and me. Which are needed to help make my students the best version of themselves as well as the best Black female (teacher) version of myself” (MR3). Starr recognized how the actions of her students modified her own and how her actions would impact them. Tam saw how liberatory power worked when making physics relevant to students’ lives. In his view, “the students who do not do well in Physics class believe that the subject is irrelevant to them” (R3). To change this, Tam recognized that “the only solution to this problem is to introduce the Historical Literacy Responsive framework to our classroom” (R3). Each participant recognized how modifying their actions and developing relationships with students would impact and empower both students and themselves within a system that focused on repressive power.

Within their practice, participants focused on building relationships with their students and fostering a positive learning environment. Madelia recognized that “it’s really important to get to know the students and meet them where they are and provide them with things where they feel comfortable learning and where they feel the learning is attainable” (MR3). By doing this, Madelia embraced liberatory power so that students would be activated to take control of their learning. Starr also realized the impact liberatory power had on her teaching. She found “when [my students] don't believe in themselves, they will do it because I believe in them” (I2). Participants' willingness to recognize and embrace liberatory power in their practice was rooted in their alignment with social justice ideologies. Madelia wanted “to also incorporate the HRL framework outlined by Muhammad (2020) and focus on identity because I feel like a lot of students need to see themselves in the curriculum or be inspired by someone who they resonate with” (R2). Starr worked to show her students they mattered by “attending their basketball

games" (I2). She found after doing this, her students "they're not so, 'Well, I don't want to say the wrong answer.' And [for Starr] to be like, 'It's okay… We always can't be right. I'm gonna be wrong sometimes too.'" (I2). In order to understand how this thinking appeared in participants' practice, I analyzed their field performance observations conducted by their university supervisor, Mrs. Reid. I paid particular attention to the positive learning environment indicator (Figure 4.4). This indicator most aligns with how relationships appear and reflects the power dynamics in a classroom.

Figure 4.4

The Positive Learning Environment Indicator from the Observation of Field Performance Rubric

INDICATOR		*Advanced*	*Proficient*	*Developing*	*Insufficient*
LEARNING ENVIRONMENT					
1-LE	**Positive Learning Environment: Promotes a positive and safe learning community.**	Promotes a positive (trusting, caring, and respectful) and safe learning community: facilitates learners in self-regulation, positive student-student and teacher-student interactions; communicates and maintains high expectations; and establishes a physically safe space.	Promotes a positive (trusting, caring, and respectful) and safe learning community: facilitates learners in self-regulation and positive teacher-student interactions; communicates and maintains high expectations; and establishes a physically safe space.	Promotes a positive (trusting, caring, and respectful) and safe learning environment: facilitates positive teacher-student interactions; communicates and maintains high expectations; and establishes a physically safe space.	Promotes a learning environment that does not facilitate learners in self-regulation, or positive student-student or teacher-student interactions, does not communicate and maintain high expectations, **AND/OR** does not establish a physically safe space.

Overall, participants demonstrated consistent growth and high achievement within this indicator. By the second fall observation, participants scored either proficient or advanced. In Table 4.10, Madelia quickly began to score advanced. Jacob and Azula both mimic this growth. Starr oscillated between proficient and advanced throughout her observations. Tam showed continual growth throughout the fall semester. The scores on this indicator demonstrate participants' dedication to promoting a classroom that uses liberatory power.

Table 4.10

Scoring on Positive Learning Environment Indicator for Observations Conducted by Mrs. Reid

Participant	Fall 1	Fall 2	Spring 1	Spring 2	Spring 3
Azula	Advanced	Advanced	Advanced	Advanced	Advanced
Jacob	Advanced	Proficient	Advanced	Advanced	Advanced
Madelia	Proficient	Advanced	Advanced	Advanced	Advanced
Starr	Proficient	Proficient	Advanced	Proficient	Advanced
Tam	Developing	Proficient	Advanced	Advanced	Advanced

Agency

Once participants began to recognize the power they held, they started to think about and use their power. Brookfield (2005) defines agency as "the capacity to exert influence on the world through the exercise of individual and collective power" (p. 48). Before participants started to become agents of change, they first had to confront how they were channeling disciplinary power. Disciplinary power is wrapped up in self-surveillance, which helps an individual maintain the norms set forth by culture and institutions like schools (Foucault, 1977). By exercising disciplinary power, individuals conform to systems and behaviors that maintain hegemony. Starr recognized how she channeled disciplinary power while learning to be a science teacher. For her, learning to teach "had to do with the trial and error and me being scared to make a mistake being a teacher. I feel like that hindered me as far as trying stuff because that fear of making a mistake" (I3). Starr's fear of making mistakes limited what she was willing to try in her practice related to social justice and 3D science teaching and learning ideologies. This limitation challenged Starr to contest hegemony in her practice. However, by the end of the program, Starr felt like she had overcome the disciplinary power she exerted upon herself and transitioned into an agent of influence. Starr decided to use her agency to show her students "how to be proud of who they are and where they come from by showing them that we

(including teachers) are human just like them. We have emotions, we make mistakes, and we all go through struggles in life" (R2).

On the other hand, Tam continually struggled with disciplinary power, hindering his own ability to exercise. An example of this can be seen when Tam discussed an ideology at his school called "compassion over complaints". As he said, "the teachers pass [students] with compassion… The symbol for this that everybody talks about is compassion over complaints. They just pass failing students… So they won't be left behind. But as they go to my class, they barely know anything. Failing, I have no choice but [I'm] gonna have to pass them too" (I3). Tam saw no other option but to conform and uphold the hegemony of his school instead of using his agency to exert influence on the system. Meanwhile, Madelia, Azula, and Jacob entered their placements already aware of their agency. Madelia stated prior to arriving that she was "much more ready to advocate for my students to make sure they are getting the things that they need to be successful" (R2) after reading the summer methods course texts. However, all participants eventually found a way to exercise agency in the classroom to varying degrees.

Participants used agency in different ways in their practice. Starr and Madelia both demonstrate the two ways this was seen. Starr used agency in how she approached her planning, instruction, and assessment. She credits the ITP program for how "it has changed my way of thinking when it comes to teaching for the better. I never thought it being like, my own art, like me teaching, whatever how I wanted to teach it. To me, when I heard about teaching, I felt like it was being told to the teacher what to say" (I1). Through thinking of teaching as her art, Starr was able to exert her individual power in her world and push back on the status quo of science teaching. Madelia approached engaging in agency as empowering her students. Her readings around social justice in the classroom influenced much of this approach. It was important for Madelia to "ask my students what they thought of the lessons and what else they would like to

learn about to give them some control of their own education…" (MR3). Madelia's alignment with social justice ideologies meant she sought to unmask power for her students. This was seen in her lesson about the atom and its connection to WW2. In this lesson, Madelia had students engage with the role of African-American scientists in developing the atomic bomb. For this to happen, "President FDR issued Executive Order 8802, which declared, 'There shall be no discrimination in the employment of workers in defense industries and in Government, because of race, creed, color, or national origin.' It was the first Presidential directive on race since Reconstruction. The order also established the Fair Employment Practices Committee to investigate incidents of discrimination" (LP). She then had students engage with the actions of the African American scientists and FDR in changing policy. Through this lesson, Madelia involved students in talking about power dynamics. In order to analyze how these ideas translated into participants' practice, I returned to their field performance observations conducted by their university supervisor, Mrs. Reid. I paid particular attention to the assessment for learning indicator (Figure 4.5).

Figure 4.5

The Assessment for Learning Indicator from the Observation of Field Performance Rubric

	INDICATOR	*Advanced*	*Proficient*	*Developing*	*Insufficient*
	ASSESSMENT OF AND FOR LEARNING				
1-AL	**Assessment for Learning: Uses assessment tools for both formative and summative purposes to facilitate learning and to adjust instruction.**	Uses appropriate formative/summative assessment tools to document learners' prior knowledge **AND** new learning to facilitate learning. Adjusts instruction for the whole class, groups of learners, and/or individuals.	Uses appropriate formative/summative assessment tools to document learners' prior knowledge **OR** new learning to facilitate learning. Adjusts instruction for the whole class, groups of learners, and/or individuals.	Uses appropriate formative/summative assessment tools to document learners' prior knowledge **OR** new learning to facilitate learning.	Uses inappropriate formative/summative assessment tools **OR** does not document learners' prior knowledge or new learning to facilitate learning.

I selected this indicator because it measures teacher candidates' ability to adjust instruction based on feedback gathered from assessments. To successfully do this, teacher

candidates must recognize and acknowledge the agency their students hold while using their agency to modify their actions during a lesson. For instance, in Starr's second fall observation, Mrs. Reid stated, "I was impressed with the feedback you gave to the students and, in turn, the feedback they provided." This supported Starr's ability to adjust the lesson activity to better meet her students' needs. In table 4.11, participants are shown to be discovering how to best use their agency in the classroom through the variety of scores from the rubric. In the spring semester, all participants achieved advanced in all of their observations conducted by Mrs. Reid.

Table 4.11

Scoring on Assessment for Learning Indicator for Observations Conducted by Mrs. Reid

Participant	Fall 1	Fall 2	Spring 1	Spring 2	Spring 3
Azula	Proficient	Advanced	Advanced	Advanced	Advanced
Jacob	Developing	Proficient	Advanced	Advanced	Advanced
Madelia	Proficient	Advanced	Advanced	Advanced	Advanced
Starr	Proficient	Proficient	Advanced	Advanced	Advanced
Tam	Developing	Advanced	Advanced	Advanced	Advanced

Based on this observation indicator and other data provided by participants, it is evident they engaged in agency, but in the way that best suited their context and ability to work through the disciplinary power they enacted on themselves.

Link to TCSR

Contextual Factors

During the ITP program, participants were able to unmask power due to the types of support they encountered that encouraged them to question, recognize, and then use their power to influence others. For Starr, this was in her relationship with her mentor teacher, Mr. York. When Starr first entered her placement, she was worried. She was looking for Mr. York to tell her what to do, but she quickly found that was not going to happen. As Starr put it, Mr. York

"was more like, 'Girl, do your own thing.' That was stressful because it's like, 'Do my own thing? I don't have the stuff! I don't have anything! I don't have nothing!'" (I3). Starr later found the support of Mr. York to be empowering, helping her overcome the disciplinary power she exerted on herself. Starr was "very thankful for that. [Mr. York's] always like, 'If you don't get it right today, it's okay. You come back tomorrow to them.' I feel like this is what I needed for the kind of person I am to loosen up" (I3). Mr. York's steady support enabled her to recognize and use her power in the classroom. Meanwhile, Madelia unmasked her power through reading texts required in the ITP program. The books lead Madelia to reflect on and recognize the amount of power she held as a White woman. Madelia "lived a life of privilege and never knew how good I had it, until recently" (R1). She attributed this new way of thinking to the texts, specifically on social justice. For her, "these books… have taught me so much about the things I have been missing from my education and upbringing" (R1). As Madelia progressed through the ITP program she continually revisited two specific texts: *We want to do more than survive: Abolitionist teaching and the pursuit of educational freedom* (Love, 2019) and *Cultivating genius: An equity framework for culturally and historically responsive literacy* (Muhammad, 2020). These texts inspired Madelia to engage in agency for the benefit of her students. She felt "we all have roles that we can play… and I have no problem leveraging my privilege that I know that I have to make a difference for those that need it" (I3). Madelia's main supporting contextual factor emerged from a broader cultural context, but her thinking was evident in her practice in the classroom context, as seen above. Starr's support came from the classroom context. She was able to make the connections between how power in the classroom flited up to broader cultural contexts. This was seen when Starr made the connection between Black joy and instructional strategies. Their experiences demonstrate how different layers of contextual factors lead to participating in the learning task of unmasking power.

Personal Factors

Participants drew on various personal factors which reminded them of their own power. Starr found a source of personal strength from her mother, a third grade teacher. Whenever Starr felt low about her ability to teach, she sought encouragement from her mom. Starr gave this example: “I was like, ‘Mom, I feel so stupid. I'm just now making that connection.’ She was like, ‘Girl, you'll be okay. I'm third grade, and I still make connections. Where did that come?’ Yes, that was some of the stuff. I was like, ‘Oh, exactly’” (I3). Not only was Starr, once again, being reminded it is acceptable not to be perfect, she was being reminded both by her mother and a fellow teacher. This was liberating to Starr and gave her insight into being a continual learner as a teacher. Madelia drew on her experience of pushing back against repressive power while working at an aquarium and as a provisional teacher. As Madelia told it, “Like at the aquarium, I got in trouble for that all the time, when I worked in education… I was the one who vocalized like, this isn't fair. We're frustrated. We need to fix this… I'm that person. I don't care. I'd rather just be like, ‘This isn't fair to like everybody… and you should fix it’” (I3). Madelia used her agency to advocate for herself and others. Other participants reflected and thought about prior experiences with power and how their actions were modified by others. As participants moved from recognizing to questioning to using their agency, their teacher identities also developed.

During the January and May interviews, participants were asked if they had started to think of themselves as science teachers (Table 4.12). In the responses, it became evident that participants varied in their thinking of themselves as teachers, but they related to the power participants felt they held in the classroom. Madelia already believed herself to be a science teacher. This is unsurprising since she had already been a teacher-of-record before entering the ITP program. Starr’s recognition of how she and her students’ actions modified each other caused her to notice how different it felt in the classroom, leading her to believe, “I’m really

doing this" (I2). In May, Starr felt like a science teacher but underestimated her impact on her students. The students' actions of writing messages on the white board modified how Starr felt about her impact. Tam's thinking about his teacher identity also shifted due to students' actions.

In January, Tam stated he was beginning to think of himself as a teacher, but his confidence appeared shaken in May. Tam believed his students "still see me at the student" (I4). In Tam's case, the power of students combined with Tam's disciplinary power was seen to modify his thinking and limit his ability to recognize his own power. Both Jacob and Azula spoke about experiencing imposter syndrome but at different times. While Azula mentioned this in her January interview, Jacob spoke of continuing to experience this phenomenon in May. By expressing their wrestling with imposter syndrome, Azula and Jacob were also wrestling with disciplinary power. By comparing themselves to the status quo of what they believe a teacher is, each internalized the hegemony of what a science teacher should be based on the system. However, unlike Jacob, Azula recognized how she and her students' power impacted each other. Overall, the varying degree to which participants claimed to think of themselves as science teachers was driven by their ability to unmask the power of themselves and other stakeholders in the educational system. Once participants began to think of themselves as science teachers, they reclaimed reason to determine what they valued in the classroom

Table 4.12

Participant Responses to "Have you started to think of yourself as a science teacher?"

Participant	January Interview	May Interview
Azula	"Absolutely. Yes. My kids think of me as the science teacher. You know, like, 'I have two science teachers. I have [mentor teacher]. I have Ms. Azula.' It's very much ingrained for them… They know I have as much content knowledge as I need. I have as many of the resources as I need to help people out. Kids come see me before and after school for help. I very much feel like I'm playing the part. I get the imposters syndrome sometimes. It's not as bad as it was last semester. I feel like it was a little worse last semester. Because I was like, 'Am I a teacher? Am I supposed to be here?' This semester … usually only happens on Sundays, honestly."	"Absolutely. So, I definitely… I still hold… I don't want to say power, but I still hold that dynamic within my classroom, where I'm obviously the more knowledgeable and able to instruct them, though I learned from them all the time. I definitely feel like I'm part of the teacher role. I feel like I can use my age to an advantage to connect with my students a lot better… I've seen that a lot of them are able to come talk to me before, after school, before after class about things in their personal lives."
Jacob	"After this week, a little bit. This week actually went really well. It started last week on Friday. I showed them how to use a microscope, and I went through the microscope… So, we did it as a class, and I modeled for them how to use it. Then I was like, 'Here are slides go practice. We're doing a lab where you're gonna look at your own cells.' And they were like, 'Okay, that's weird and gross. But sure.' They start doing it. They're like, 'Oh, this is actually kind of cool.' Anytime they find anything, like they're proud, and they call me over to check it for them. We actually did the experiment and they were excited about it. Just going through this week, it was fun. I could tell that a lot of them actually learned something, which was cool. That's a little bit getting there."	"Sigh… sort of. I have a little bit of impostor syndrome still. But, I'm still very new to it. A year ago, I had zero teaching experience. And now I feel like I can do it. I'm not where I want to be necessarily. I have the foundations from the program. I know that I can do it, but there's more that I want to do. We're getting there. I'm sure. Two months into this school year when I'm in my own class, and it's my stuff, and the students are my students, and I have the freedom to do whatever I want. And I'm not being observed every day. When there's not less pressure, but more freedom to do things the way that I want to do things…yeah."

Participant	January Interview	May Interview
Madelia	"Definitely last year when I was teaching science, but also I think, while I was at the aquarium teaching."	
Starr	"I have. I guess some days when I'm not going, going, going, going. I'm like, 'Oh my gosh, I'm really doing this. This is it.' Or when I teach something, and it's an aha moment and they get it… When they were getting the base pairing, they were so excited. It was kind of like, 'Okay, okay, this is teaching them science. Teaching them how DNA works and things like that.' So, I have, I have." Would you say that you started thinking of yourself as a science teacher like last sometime last semester, or like this semester? "I probably have to say this semester. Cuz I look at it as a difference that I feel, that I see. I mean, the students and what they are doing, and so I feel like when I started to see that it was kind of like, 'Okay, [Starr] help me up here, Miss over here.' That warms my heart. It's like. 'Please be comfortable enough to let me know if there's something you don't understand. So that way I can slow down, come to you, one on one explain it to you or if it's something that everyone is then let's pause, come collectively together on this.' So yeah, I will have to say this semester."	"I actually do. Actually, Friday, the last day of school, it was really an eye opener for me. Honestly, for me, I felt like I didn't make that much of an impact. Then, Friday or during the week, I was like, 'Guys, this is my last… Friday will be my last day.' A lot of them are like, 'What? Where are you going? Who's gonna teach us now?' And I'm like, 'Ah, [Mr. York] is right here. He can teach.' It was just... then they write messages on the board. And then even my mentor, like, it was just really like fulfilling to see all of that."
Tam	"I started thinking to myself I did kind of good. I'm confident and I'm ready. If they want me to be a full time teacher right then in when we're getting paid, right that I'm willing to do it right now. No hesitation. Just gonna do it. I'm just gonna If I don't know anything, I'm just gonna find out overnight. Is just, "Okay, I can do this." I like this. I know I can do this. I can explain it. I can show them these cool things."	"I feel like I'm...ok I can teach? I can sit there and teach. But...sort of...sometimes, I sometimes I'll go into the school and they still see me at the student, even though I start dressing up and everything."

Reclaiming Reason

In order to use reason, an individual must "assess evidence, make predictions, judge arguments, recognize causality, and decide on actions where no clear choice is evident" (Brookfield, 2005, p. 55). Critical theorists, such as Horkhiemer, Adorno, and Althusser, argue reason has been instrumentalized in society. Other theorists, like Schutz, Luckmann, and Habermas, believe reason is formed within the lifeworld individuals function within. Regardless of which of these critical theorists are being examined, reasoning is threatened and becoming lost. The adult learning task of reclaiming reason occurs when adults are able to apply reason to all aspects of their lives and decide what they value in them (Brookfield, 2005). Broadly, adult learners should participate in discourse and communicative action to question their assumptions, reclaim reason, and apply it to their lives (Brookfield, 2005; Habermas, 1987). While analyzing participants' data, I looked for when they engaged in elements of reason and how they were able to employ it during the ITP program. This learning task demonstrated how participants came to decide what they value as teachers by recognizing their own assumptions and causality in their actions. In this section, I will highlight the experiences of Starr and Jacob, who were selected due to how they reclaimed reasoning to determine what they value in a classroom setting (Starr) and the educational system (Jacob).

Assumptions

Participants found themselves experiencing a variety of emotions throughout the ITP program. Most were tied to their assumptions about teaching, students, learning, and the education system being confirmed or challenged. Using Habermas' work with the lifeworld, Brookfield expands on situations that cause individuals to confront their lifeworld assumptions. A clear definition of the lifeworld from Habermas (1987) is "the lifeworld forms the indirect

context of what is said, discussed, addressed in a situation" (p. 131). Brookfield expands on this definition by offering that the lifeworld is "all those assumptions that frame how we understand our experience of life and how we try to convey that experience to others" (p. 238). Identifying the lifeworld in and of itself is challenging, but aspects of it, like assumptions, can be seen in moments when people need to respond to a situation with action (Brookfield, 2005). Starr's work with reclaiming reason mainly centered on her classroom and determining what she valued in her practice. She often encountered her assumptions and own experiences around learning being challenged in her placement. For example, Starr was introduced to group work in the classroom during her placement. For her, "When I envisioned teaching, I guess for me, because I didn't, I wasn't allowed to do a lot of group work in school. I feel like that's another thing that's kind of new to me is letting the students be in groups" (I2). Starr assessed the evidence of how working in groups informed her students' learning. She found, "I liked [group work] and partners because it lets them interact with other people that are not like them. Sometimes I let them choose, sometimes I pick them for them. I know its students that they normally probably wouldn't choose on their own" (I2). Starr used this evidence to confront her assumption about group work. By challenging her assumption of how to best teach her students, Starr found herself shifting her thinking. As she said, "[small groups] have changed the way I'm thinking about lesson plans, and how I'm going to teach something" (I2). The inclusion of group work challenged Starr's teaching-related lifeworld; however, she pushed back on her assumptions of how students best learn and incorporated group work into her practice. In particular, Starr's reasoning for this lay in her understanding of how to include social justice in her classroom by encouraging students to interact with others who are different from themselves.

For Jacob, his experience with the various teachers in his placement revealed an assumption based in a broad cultural belief: all teachers believe all students matter. He explained, "In many of our classrooms, teachers don't believe every student is capable. They so often give up on students and set low expectations based on personal prejudices and past experiences. It becomes a self-fulfilling cycle where teachers set these low expectations, and research has shown that students will only work to the level that is expected of them. In turn, students only perform to their low expectations, and the teachers' backwards thinking is validated" (R3). Jacob saw this in action during his time at his placement, River Mill Middle School. He described the expectations of his mentor teacher as "the doesn't care what you do, can't save everybody, gonna play a video, and hope you succeed type" (I1). Jacob depicted another seventh grade science teacher as "hard, the dictator type…students always sat backwards facing the back wall so you could see what they were doing. And silent lunch if they spoke during class and made kids cry, often" (I3). Even though Jacob's assumption about teachers' attitudes and expectations for students was challenged, his belief shifted in one word: all teachers *need to* believe all students matter. He confirmed this shift in his thinking when discussing the importance of social justice in the classroom. As Jacob stated, "Like cultivating and genius, abolitionist and teacher are not new words, but they are a powerful new phrase when combined. To be an abolitionist means to teach for freedom… To be an abolitionist teacher we must drastically change the way we teach, hence the abolitionist part. That is a strong word that should not be taken lightly, but exactly what our education system needs…there is still so much work to be done" (R2). The experience Jacob had in his belief about a teacher's role demonstrates how assumptions and the lifeworld impact how teachers engage in the micro (classrooms) and the macro (educational system). Other participants found themselves confronting assumptions about their contextual factors, such as the schools and

the system in which they function (Table 4.13). The ideas participants had about schools and the system they are part of were challenged based on broad cultural assumptions around education.

Table 4.13

Participants' Challenged Assumptions

Participant	Context	Assumption	Experience
Azula	School	Disciplinary issues are spread fairly equally amongst the student population.	"The equity audit is pulling out a lot of things that are unseen at Palomino in terms of students that are special education students who have been disciplined…the number of those students is way higher than students who do not have 504s or IEPs…that's a big deal. That's really significant…that number represents a lot of freaking students" (I2)
Madelia	Classroom	Student engagement is limited to what is traditionally thought of as science.	"I didn't realize that I could incorporate so much more into science" (MR2)
Tam	School System	The school district has the best interests of all students in mind when making policy decisions.	"I am also outrageous that the county removed Physical Science and put students into Physics… the majority of the kids they are putting into the Physics classrooms haven't yet reached the necessary math level… These kids are supposed to be introduced to science conceptually in Physical Science classes; Instead, they are being pushed into Physics class where it is supposed to be more math-orientated…How can these kids be taught without knowing the math?" (R2)

All participants acknowledged and often confronted their assumptions that colored their lifeworld due to situations that demanded action. Starr encountered this situation every time she led classes in her placement. I wanted to see how Starr either did or did not try to incorporate group work into her practice. To do this, I reviewed Starr's observations from her mentor

teacher, Mr. York, and her university supervisor, Mrs. Reid. I looked for any mention of group work, instructional strategies related to group work, and student involvement. In Table 4.14, Starr's effort to make her teaching more student-focused through group work can be seen.

Table 4.14

Feedback to Starr from Observers centered on Group Work or Lack Thereof

Date	Observer	Feedback Area	Feedback
9/25/2021	Mr. York	Strategy for Improvement	"Think-pair-share, working in pairs"
10/06/2021	Mrs. Reid	Overall Comments	"Students did participate some during the lesson. You need to make sure all the students participate or are at least willing to participate."
11/10/2021	Mrs. Reid	Overall Comments	"Students were on task throughout the activity… You went from group to group checking progress and asking them to explain things to you."
02/03/2022	Mr. York	Strengths	"Active learning for all students. High level of engagement."
03/08/2022	Mrs. Reid	Overall Comments	"Students were very interested in side conversations, until you started the group work. They did participate in these and were completing the work as they moved from one set of facts to another."
03/22/2022	Mr. York	Strategy for Improvement	"Provided a variety of resources to improve student learning and involvement."
03/25/2022	Mrs. Reid	Positive Learning Environment	"Students are comfortable in the classroom, and it is arranged for easy transition from single to group work."

The observation feedback is supported by Starr's reflection on her practice in her January interview. Starr revealed, "Last semester, I did more guided notes, and then the activity. This semester changed it up to where I didn't do as many notes at one time and broke it up and then let them do activity trying to see does that work better? I feel like letting them do their activities… just having them talk amongst each other… they're taking ownership of their learning" (I2).

Starr's lesson plans also shifted from being teacher-centered with only individual student work at the beginning of the fall semester to more student-centered. Her instructional strategies included stations, lab investigations, and group activities constructing models (LP). The modification in Starr's practice was influenced by the changes she saw in her students. For her, "definitely seeing the difference between when we are doing our guided notes how they are… And then once the setting changes over to them being able to be free, talk, have their hands on, and be able to discuss what is actually going on that we did in the notes" (I2), led Starr to recreate her lifeworld and reclaim reason. Starr's challenged assumption around group work in the classroom was concrete and clear in her practice.

The actions that best embodied Jacob's challenged assumption were captured in how he engaged with students. If Jacob truly believed that all students need to matter to teachers, he would most likely display this belief in how he built relationships with his students. When asked about his strengths as a teacher, Jacob responded that relationship-building would be his top strength. As he said, "[relationship building] was what I was most worried about… during the fall semester, I didn't teach a ton, you know, I was mostly observing. I was just getting to know the kids. I was just treating them like humans. It wasn't a power play. Like, 'I'm the teacher, you do what I say', I don't… I just treat them like humans" (I3). This genuine interaction was observed many times by Jacob's mentor teacher, Ms. Campbell, and his university supervisor, Mrs. Reid (Table 4.15). Jacob's rapport, high expectations, and safe classroom environment were mentioned in almost every observation.

Table 4.15

Feedback to Jacob from Observers Demonstrating how Jacob Shows his Students Matter

Date	Observer	Feedback Area	Feedback
10/19/2021	Ms. Campbell	Observed Strengths	"Great student conversations that dispelled misconceptions and held them accountable of accurate information."
10/21/2021	Mrs. Reid	Positive Learning Environment	"Students were very comfortable and accepting with you. They… did not hesitate asking questions as needed throughout the class period."
11/17/2021	Mrs. Reid	Observed Strengths	"Good rapport with students."
01/25/2022	Ms. Campbell	Overall Comments	"His energy is positive, and sincere he gets his students…"
02/16/2022	Mrs. Reid	Observed Strengths	"You have developed a very good rapport with the students, and they respect you."
03/02/2022	Mrs. Reid	Positive Learning Environment	"It is evident that you have high expectations for the students."
03/07/2022	Ms. Campbell	Learning Environment	"Students enjoy hands on activities because environment is safe to ask questions without embarrassment or shame."
03/09/2022	Mrs. Reid	Knowledge of the Learner & Identity Development	"You seem to have a good grasp on the development of the students. You have grouped them and they peer tutor as needed."

Not only was this behavior recognized by his observers, but other administrative staff in the school noticed his relationships with students. Jacob stated, "Spring semester, my first day of class, the instructional coach came into the classrooms like, 'We want you to mentor these two boys that were in your class last semester for this whole semester.' That was really cool" (I3). However, Jacob relayed the mentor program had a slow start. Because of this, he took it upon himself to seek out these two students. Jacob explained, "[The mentor program] took a while to

get going. She mentioned, ‘we’re gonna hit you with more information.’ No information ever came. I found their teachers and asked them if I could just eat lunch with them once a week. I ate lunch with one one day and the other the other day just to catch up, like a weekly type deal, check-in, see how everything was going” (I3). Jacob’s assumption that all teachers believed all students mattered was challenged. After observing how students were treated and the impact it had on them, Jacob worked to be the exception in his placement. Jacob reclaimed reason by questioning his assumptions about other teachers’ behavior with students to renew and recreate his lifeworld to galvanize his belief that all teachers need to believe all students matter.

Recognizes Causality

Participants observed, engaged, and often defended their ideas around education, specifically related to social justice and 3D science teaching and learning. They found the ideas they came to value in their teaching were new or different to the other teachers around them in their placement. Because of this, participants were often forced to recognize the causality between their thoughts and actions. This aspect of reasoning was highlighted by Brookfield in the work of Horkheimer’s (1947) *Eclipse of Reason*. Horkheimer (1947) claims reason has become formalized where the focus is means-end thinking for the short term. Brookfield (2005) added this kind of reasoning is “inherently conformist and clearly an ideological creation” (p. 71). This dovetails into the idea that what is good for the group is good for the individual or “the majority principle.” Pushing back on this assumption, Brookfield (2005) suggests using causality to move past accepting short-term reasoning and toward questioning abstract universal reasoning for long-term application. An example of what all participants experienced can be seen in how Starr was challenged with connecting content to students’ lives. Starr found herself confronting her assumptions about how to best learn biology. Starr felt “like the relatable part… it's the part

that I struggle the most with just because, again, I wasn't taught that way. I feel like I've learned biology and like, the specs, but as far as relating them out to certain things, sometimes it's a harder connection or like to spit out" (I2). Starr recognized causality in how her students learned content and related it to their lives. She quickly came to value making her content relatable to students. Starr thought, "For instance, a lot of times we learn things based on the experiences that we go through… that shapes the way students think, remember, and solve problems. Therefore, using open-ended questions is a good way to activate students' prior knowledge by allowing them the opportunity to connect and express their own experiences (their culture/home life) to make sense of why and how a phenomenon occurs" (R3). Starr's ability to recognize the causality between how she taught her students and their ability to learn science best emerged from her acceptance of social justice ideologies and 3D science teaching and learning. By recognizing and acknowledging her students' cultures and experiences, Starr incorporated strategies to support her students in believing they matter to her (Love, 2019). Starr blended these strategies with 3D science teaching and learning to include phenomena related to students' lives and identities. This instructional strategy was used by all participants, including Jacob.

Jacob engaged with causality in deciding how he wanted to teach science to his students. For Jacob, "a big reason why I started this program in the first place is there's growing mistrust in science, and most of those issues stem from a lack of understanding of the nature of science" (I3). Because of this, Jacob recognized the importance of not only teaching students disciplinary content but also how to think critically. This thinking emerged in how Jacob wanted to present science to his students. He stated, "Science isn't, it's not separate from the real world… So when you make it seem like its own entity, you can only do it in school, and it can only be done by old White males, then it seems inaccessible" (I2). For science to be accessible to all students, Jacob

came to value the ideas of the HRL framework and 3D science teaching and learning. In particular, Jacob realized students could access science by combining these two frameworks. He focused on "making [science] relevant to them, and using relevant examples" (I1) while using 3D science teaching and learning so that students could have an "understanding what science is…it's our best explanation of the world at the time, but it's not concrete" (I3). By recognizing this causality, Jacob found that "3D teaching is the cream of the crop for modern education…The DCIs, CCCs, and SEPs are the holy trinity of science education, and they are the starting points for allowing students to understand a small part of this world they have no choice but to be on" (R3). Jacob and Starr, along with other participants, recognized the link between how they thought about abstract ideas like social justice and teaching science and how they grew in developing their lessons.

To better understand how participants engaged in reclaiming reason, I looked at their data over time in specific areas that aligned with recognizing causality. For Starr, I focused on how she worked to better incorporate relatable or "real-world" examples into her lessons for students. Starr explained how it could be challenging to do this. As she said, "I was teaching about osmosis and one of the relatable experiences was I actually asked [the students] have they ever put salt on a slug... Being able to grasp things that you know… trying to find experiences that I would think they would have to relate to what I'm trying to teach… You're trying to make sure that it makes the right connection that it needs to" (I2). Yet, over her time in her placement, Starr grew in her ability to relate content to students' lives. Being able to do this was an area of focus for Mr. York, Starr's mentor teacher, in his feedback (Table 4.16).

Table 4.16

Mr. York's Feedback Concerning Starr's Ability using Relatable Content for Students

Date	Artifact	Feedback Related To	Evidence
9/25/21	Observation	Suggestion for Improvement	"Knowledge of the learner"
10/5/21	MT Midterm Semester Conference	Makes content relevant to students' lives and connects content to other subject areas	Scored a 4 out of 5
11/9/21	Observation	Suggestion for Improvement	"Making the content relatable"
3/22/22	Observation	Observed Strengths (OS); Suggestions for Improvement (SI)	"[Starr] continues to provide real-life instances to help relate the content to the students" (OS) "Continue to stay current with your methods and ways to relate the content" (SI)

Table 4.16 demonstrates Starr's commitment to growing and improving in connecting content to students' lives throughout her placement. Once Starr recognized the causality between this practice in her teaching and her students' learning, she was determined to implement it into her teaching for the long-term. Throughout his lesson plans, Jacob demonstrated his growth toward questioning abstract universal reasoning around how to best teach critical science education to seventh graders.

As I thought about how best to display Jacob's ability to recognize causality in order to reclaim reason, a particular statement stood out to me. While discussing the importance of practicing constructing lesson plans, Jacob stated, "Practice not only with making lesson plans, but like practice in implementing the social justice stuff. When I first started making lesson

plans, I was like, ‘Alright, I gotta do this and this, and this first.’ [I] would go back and try to squeeze [social justice] in, and it was clunky. I had to reframe the way that I made lessons in the first place and make that almost like a central aspect to it. Because [social justice] is a central aspect, it's equally as important as the content knowledge… it's going to flow better. It's not going to feel out of place. It's not going to be weird, like, ‘Why did we just transition from genetics to the civil rights movement, just like that like, right?’”(I3). Appendix E contains elements of Jacob’s first and last observed lessons. In his first observed lesson, Jacob outlines the standards, learning objectives, and the learning segment of the lesson. While analyzing his learning objectives, it is clear Jacob has a developing understanding of implementing 3D science teaching and learning. For instance, he has incorporated science practices into approximately half of his learning objectives, has core ideas in all learning objectives, and is missing crosscutting concepts. Jacob has implemented all aspects of the HRL framework into this lesson, as seen in the learning objectives. The learning segment of the lesson starts by asking students to explain how the Civil Rights Act is connected to genetics. In his quote above, Jacob referenced this genetics lesson, where he discussed incorporating social justice as “clunky.” Even though Jacob does not explicitly state the crosscutting concept in his learning objectives, he does outline how he is using the crosscutting concept of patterns in the body of the lesson. This is the opposite of what occurs with the pursuit of identity from the HRL framework. Jacob clearly experimented with how to fuse the two ideologies of social justice and 3D science teaching and learning together in this lesson.

At Jacob’s placement school, students completed four courses a semester. This meant Jacob could reflect, review, redesign, and reteach lessons from the previous semester. Coincidentally, the last lesson observed for Jacob in the spring semester was over the same

content standard as his first observed lesson. In the learning objectives, Jacob's ability to recognize causality is displayed. Here, he has complete alignment with the stated standards through scientific practice, disciplinary core ideas, but is still missing the crosscutting concepts. Jacob again incorporates all aspects of the HRL framework into his lesson, but it is more natural and less clunky. Jacob selected a more age-appropriate way to discuss race and genetics. In the introduction of this lesson, he references the phenomenon of twins who present as two different races. This phenomenon often led students to question and wonder how this could occur. Jacob also shifted the order of assignments and reworked the animal profile activity to include small groups rather than focusing on the whole class. Jacob ultimately decided to let go of including the Civil Rights Act in his genetic lessons. However, the first lesson had a lasting impact on Jacob. In his words, "it was me talking a lot about what the Civil Rights Movement was, and how it was not that long ago. The fact that most of the kids had never even heard of it… That was kind of eye opening to me…The children that affects more than anything, don't even know what happened, or any of the people involved with it. I definitely think it's very important to add a [social justice] aspect to it" (I2). This experience led Jacob to question his long-term practice in the classroom, which ultimately contributed to him completely fusing the two ideologies of social justice and 3D science teaching and learning to create critical science ideology.

Link to TCSR

Contextual Factors

While in the ITP program, participants worked towards determining what they valued as science teachers. Various layers of contextual factors impacted what and how they came to value in their thinking around education. Starr's experience with the IAMSTEM summer camp began to lay the foundation for her to question her assumptions around teaching science. For her, "I felt

like it showed me how I can make biology and things like the experiments we're doing… just how things can be fun, how I can move towards that… seeing the students excited… I'm like, 'Okay, this is it'" (I1). This experience framed what Starr was exposed to in her placement as beneficial for students and their learning. Starr found herself open to teaching science in a way aligned with 3D science teaching and learning, and she also discovered why using social justice in her classroom was important for her while engaging in the IAMSTEM camp. She recalled, "[IAMSTEM] gave the students a chance to see someone who looked like them (Identity in HRL) or come from a place that they or their family comes from" (MR3). This resonated with Starr, and she began the process of reclaiming reason, challenging the ideologies she brought with her into the program. Madelia's experiences with the IAMSTEM program mirrored Starr's. She found herself beginning to question her assumptions about teaching science. For instance, Madelia realized, "It's really important to get to know the students and meet them where they are and provide them with things where they feel comfortable learning and where they feel the learning is attainable" (MR3). Throughout these contexts, multiple levels of factors are engaged. Starr and Madelia made connections across the ITP program to broad cultural contexts.

Jacob's experience at the beginning of the ITP program also set the stage for how he entered practicum and sought to reclaim reason. Instead of IAMSTEM, Jacob found the texts from the summer methods course pivotal to backing his thinking about education. Jacob's assumption that all students should matter to all teachers was supported by Muhammad's (2020) and Love's (2019) texts. As Jacob reflected, "reading the two books… like those really drove in the fact that if you don't do those things, then you're not reaching those students in the way that they need to be reached" (I1). Jacob took this confirmation of his thinking with him into his placement. When he observed his mentor teacher engage with students, Jacob was able to

reclaim reason by recognizing causality. For him, “some of the things that [Ms. Campbell] says about students and the way she tries to manage kids… after reading *Love and Logic*… I'm like… I don't feel like I'm in a place where I can tell her not to do those things. In my head, I'm like, this is the opposite of what you should be doing” (I1). Here, Jacob was impacted by ITP program level factors, school factors, and broader social factors, such as how to engage with children. The multiple levels of interaction between contextual factors worked to reveal aspects of Jacob’s lifeworld, which led to him recreating his assumptions to better fit the experiences he had.

Personal Factors

Each participant entered the ITP program with an existing lifeworld formed by their experiences and assumptions of the world, particularly in education. Starr entered the ITP program after working in optometry for approximately six years. During that time, she watched and heard about her mom’s experiences as a teacher. When COVID happened, Starr took advantage of the change to her job to begin preparing to enter an ITP program. Starr was glad she selected Victoria Prefecture University “because the way that we are getting taught and handled… that was the way I was going towards anyway” (I1). Starr’s way of thinking was already beginning to align with the ideologies and approaches to teaching and learning science that were present at VPU. Starr thought, “it worked out and what I was looking for and getting the resources to help myself get to what I envisioned or wanted my classroom or what kind of teacher I want it to be” (I1). Starr’s vision for her role as a teacher was “encouraging the students… keep them pushing to move on to the next step… believing in them even when it's hard” (I1).

Entering the program with this belief and having it reinforced through the various resources encouraged Starr to challenge assumptions that ran counter to the ideologies of social justice and 3D science teaching and learning while simultaneously recognizing causality in her thinking and actions.

Jacob had a similar experience. Like Starr, Jacob experienced a different profession before deciding to enter the ITP program. His "background is in conservation work, and has worked with exotic animals" (O1). However, Jacob's thinking shifted as he experienced working in the veterinarian field. As he said, "my priorities have changed… I never cared about people as much as I did, like animals and stuff. Animals were my driving force for science. I still love animals. But, I also started seeing the world for what it is, realizing things, and growing up. I was like, 'wow, I feel like I should focus my attention elsewhere'" (I1). It became important to Jacob to "share his love of science with his community" (O1) and "to instill confidence in people at a young age" (O1). These core ideas Jacob entered the ITP program with were cultivated and solidified as he engaged in different experiences during the program. Even though Jacob was already primed for the ideas presented in the ITP program, he still had assumptions of his lifeworld challenged while working to recognize the causality of his and others' actions. At some level, all participants had assumptions challenged and were pushed to reflect on how their thinking appeared in their actions, ultimately resulting in them reclaiming reason.

Cross-Case Synthesis Summary

Each adult learning task outlined in the cross-case synthesis supported participants in thinking about education, students, their content, learning, and how they viewed themselves as teachers. While their level of engagement varied with each task, the core ideas of ideology, hegemony, power, and reason influenced how they decided to align with or resist the ideologies

of social justice and 3D science teaching and learning. Participants revealed moments that defined their learning in becoming a science teacher by working to challenge, contest, unmask, and reclaim these ideas. The four findings that emerged from their experiences can be seen in Table 4.17. I have drawn on the TCSR model to understand how these findings emerged.

Table 4.17

Summary of Cross-Case Synthesis

Critical Adult Learning Task	Contextual Factors	Personal Factors	Finding
Challenging Ideology	Placement	Beliefs held before entering ITP program Culture	Participants combined social justice and 3D science teaching and learning ideologies into one: critical science ideology
Contesting Hegemony	Texts Placement	Past learning experiences as science students	Participants did not have contesting hegemony modeled for them by their mentor teachers, particularly with social justice.
Unmasking Power	Support from ITP program mentors Texts	Support from loved ones Previous job experience	Participants' teacher identity development was driven by their ability to unmask power.
Reclaiming Reason	Alternative teaching experience Texts	Previous job experiences The rationale for becoming a teacher	Participants decided if they valued critical science ideology based on their ability to reclaim reason.

Contextual factors in the TCSR model are broken into levels of specificity. For instance, the broadest factor is social issues, while the most specific is the classroom environment. In this study, the ITP program was considered as a broader contextual factor. Participants did not take the same classes throughout the program nor had the same placement. Yet, when the specific contextual factors from each learning task are compiled (Table 4.17), elements from the ITP

program dominate. The most common contextual factor was the texts used in the methods courses. These texts provided students the tools to recognize and push back on the broad social issues associated with the ideas found in critical science education. Their placements gave them the space to engage with the adult learning tasks and view the broad cultural ideas at play. A key component throughout their contextual factors was having experiences that allowed them to test and see how their thinking revealed itself in their practice. Teacher candidates were able to develop or test their thinking and practice during their alternative teaching experiences in a space that felt safe to them. Participants would not have been able to have such rich learning experiences without the various mentors they met and worked with in the ITP program. Just like the contextual factors supported their shift towards embracing critical science ideologies, personal factors impacted participants' willingness to challenge their thinking.

The personal factors in the TCSR focused on elements of teaching experiences and school demographics. All participants, except Madelia, had no teaching experience before entering the ITP program. It emerged from the data that participants' prior experiences as students, in jobs, their support systems, their demographics, and any teaching experiences were personal factors. As seen in Table 4.17, various personal factors impacted participants' willingness to align with critical science ideologies. Overall, their experiences before entering the ITP program either primed or challenged them to embrace critical science ideologies. Their experiences inside the classroom as students and outside the classroom in other jobs provided participants with touchpoints to reference when engaging in the different learning tasks. An example of this was seen in Starr's experience as a student who did not engage in group work but changed her thinking and practice, so her students had a richer learning experience than she did. Madelia drew on her prior experiences working at an aquarium to better understand the power

dynamics at play in her placement. They sought support from various loved ones when navigating and developing their thinking around being a science teacher. When shifting and aligning their thinking with critical science ideologies, participants also returned to why they decided to teach. While this was all seen through the role of personal factors, it is possible that participants elected not to share certain personal factors with me. This limitation could have impacted my understanding of some personal factors. Despite some factors enabling all participants to engage in these four learning tasks, three participants engaged in the remaining learning tasks due to specific contextual or personal factors. These unique factors pointed to progress in the remaining learning tasks of overcoming alienation, learning liberation, and learning democracy.

The cross-case synthesis revealed four learning tasks in which all participants engaged. This left three learning tasks that were not engaged in by all participants. In this next section, I focus specifically on the participants who strongly engaged in each of these learning tasks. I tried to determine how their specific contextual and personal factors led them to engage with the unique learning tasks. First, Tam's experience with alienation and his attempts to overcome it colored how he engaged with critical science ideology. Then, Azula's experience with learning liberation while becoming a science teacher demonstrated how she came to embrace specific elements of critical science ideology. Finally, Jacob's ability to learn democracy solidified how he chose to engage with students and ideas found in critical science ideology.

Overcoming Alienation

Brookfield (2005) draws on Enrich Fromm's work to develop the critical learning task of overcoming alienation. Fromm was a psychoanalyst and a social philosopher. In *The Sane Society* (1955), Fromm outlined how capitalism has caused society to become alienated from

itself through oppression. Individuals objectify human characteristics, such as a person's creativity, energy, skills, and personality. Because of this, people are distanced from "the world of feelings and sensuality so that they feel dominated by lifeless objects" (Brookfield, 2005, p. 165). This leads to alienation. Alienation is "a mode of experience in which the person experiences himself as an alien…estranged from himself. He does not experience himself as the center of his world, as the creator of his own acts" (Fromm, 1956, p. 120). The critical adult learning task of overcoming alienation occurs when an individual learns to have a structuralized view of the world. By seeing how their decisions are framed and influenced by broader social structures, adult learners build an awareness of how ideologies, cultures, and economics work to shape their lives (Brookfield, 2005). While all participants experienced some form of alienation, Tam emerged as the only participant to have alienation be an impactful code. His personal and contextual factors significantly influenced the role of alienation in his ITP program experience and his ability not to overcome it.

Personal Factors

Tam immigrated to the United States from Vietnam when he was 14 years old. At the time, Tam understood no English, and his goal was the American dream of a home, a car, and a well-paying job. Tam explained why he immigrated to the United States. In Vietnam, "They don't care about people and they corrupted. The only person that go into the job decided that sons, the relative. I don't care what degree you got, you go nowhere. No, you're not getting a job" (I1). By the time Tam graduated high school he was "memorable in a way… this kid...just came here. He did the work and got really good. He did well in school without speaking much English" (I4). Tam was driven to overcome the alienation he felt from the language barrier due to what he believed others thought of him. Tam clarified, "My mindset is basically me as a

person from another country... If I can't speak the language, they're gonna judge me… they're not only going to judge me, they're gonna judge my entire people. Some people like, 'Oh, these people, they don't know anything.' That's why I was scared. I gotta study. I gotta be better" (I1). After high school, Tam experienced another perceived disadvantage in his collegiate education. Tam discovered students in his major were from the wealthier and more privileged high schools on the north side of the city where the study took place. He reasoned, "All the kids in my physics class came from the North [side]. I'm the only one from the South[side]. I guess that explains why I'm probably not do as good as them. I don't have as much resource in high school as them. They basically got everything from calculus to programming. They have all the resources" (I3). Tam's prior learning experiences and the motivation for immigrating to the United States influenced his limited shift to align with critical science ideologies.

As a critical theorist, it is easy to find the influences of Marx in Fromm's work. Yet, one area Fromm pushed back on Marx's thinking was why individuals would align with ideas and systems that oppress them (Fromm, 1965). Fromm developed the notion of social character to explain this phenomenon. Social character is "a process of ideological formation through which people learn habits and dispositions that support the existing system" (Brookfield, 2005, p. 159). The culture and society individuals develop ideologies within mold their thinking so systems are maintained. The process of social character results in conformity. The pressure for conformity ultimately comes from the individual and not outside forces since they maintain the ideologies of their culture. Unlike the other participants in the study, Tam developed his social character outside of the United States.

Tam's social character deeply reflected the ideals of equality. The experiences of nepotism in Vietnam, inequality of education, and desire to be on level with his peers

linguistically, highlighted how Tam felt alienated and at the whim of the systems he functioned in. It is also important to remember the ideologies Tam grew up with in communist Vietnam differed from the ideologies he was exposed to in the capitalist States. Tam shared that there were no differences in race in Vietnam, and the goal was to be the same. Whereas, in the States, everyone focused on race and strove to be independent. The above personal factors may explain why Tam equated social justice with equality and not equity. Tam reflected, "The only one we can deliver social justice is to have [students] do the same thing as people are doing in another school. We have to have more funding. Whatever material they have in other schools, we need to have the same thing" (I2). Tam could not overcome alienation because he did not recognize the broader social structures at play in his ideologies or culture. An example of this was observed when Tam attempted to build relationships with students. Tam blamed the differences in cultures for his inability to connect with students. Tam stated, "The culture in [the district] is mostly African-American and Hispanic. It's really hard to assimilate to that culture, because...for example, rap music, which is not really my type...many other things I just can't relate to. I just… it's really hard to connect" (I4). This led Tam to experience alienation. As he said, "[A lack of connection] just makes me feel irrelevant to [the students]. Sort of like, I'm going to class, I don't know anything common to them" (I2). Ultimately, Tam decided to "just leave [the students] alone. They just go in my classroom, everybody be quiet, and then I'm just going to teach them as a teacher. I rarely talk to them personally" (I3). While Tam recognized how cultural differences influenced his actions or lack thereof, he did not understand the role of ideologies and his culture in his decision to maintain a disconnection with students. Consequently, Tam remained alienated in his practicum program. Tam's alienation was further exacerbated by the unique contextual factors he experienced during practicum.

Contextual Factors

In contrast to the other participants in this study, Tam's placement moved during the middle of the fall semester. This move was due to his first placement school's inability to maintain the terms of placement set by the college. Tam stayed within the same school district. This move and mistreatment of Tam by his first placement school (Panther Park High School) caused Tam to feel dominated by forces outside of his control. Unfortunately, this was not his first experience in practicum with this feeling. Tam described how his first day at Panther Park High School unfolded. He explained, "I just walking along in the hallway looking for my mentor teachers… The people from my science department say, 'Hey, come into the class together.' Nobody knows what happens to my mentor teachers until the end of the meeting. They say that teachers quit" (I2). This made Tam think, "What am I? Your burden? Am I the burden on your shoulders? Am I something that you don't want to deal with? Am I something like you say waste of time or something?" (I2). Tam was not the only one at Panther Park High School to feel alienated. He observed, "I think [the teachers'] spirit already been hurt. They just like...their passion has already been killed. They don't have the resources to do it. They accept that they probably wouldn't ever be the same as whatever they expect to be" (I2). The culture of Tam's placement led to him becoming "so frustrated with my situation" (I2). Once Tam's placement shifted to Mustang High School, he felt even more alienated. At Mustang High School, "everybody just do whatever they like. There's no communication. I don't make any friends in there. The students are a little bit like zombies" (I3). Tam found himself aligning with the culture of Mustang High School by the end of his placement. He stayed isolated from other teachers and rarely interacted with his students outside of teaching. Tam's isolation and alienation lead him to conform to the norms of the school.

Fromm's view of alienation is easily seen in the concept of automaton conformity. Adults engage in automaton conformity when they are manipulated by societal expectations that lead them to strive to be the same as the majority (Brookfield, 2005). Automaton conformity is a response to becoming more aware of the freedom to choose how to think and live. Fromm (1941) identified this realization as a "source of terror rather than pleasure to most people" in his work *Escape from Freedom* (Brookfield, 2005, p. 170). This terror is an effect of realizing "one's own powerlessness and insignificance as an individual" (Fromm, 1941, p. 51), which could result in either automaton conformity or submission to a fascist leader. Automaton conformity is more alienating due to the transformation an individual experiences in becoming an automaton. Fromm (1956) described the thinking of someone who experienced automaton conformity as "I must conform, not be different, not 'stick out'; I must be ready and willing to change according to the changes in the pattern; I must not ask whether I am right or wrong, but whether I am adjusted" (p. 153). Tam wavered between pushing back on the status quo of his placements and accepting the norms of the school culture. Initially, Tam sought to implement critical science ideologies into his teaching. Yet, by the end of his placement, Tam relayed many reasons why he could not implement critical science ideologies into his practice, allowing him to conform to how science was taught in his placement.

Tam struggled with understanding how to teach his students critical science ideologies. He entered his placement and "tried my best to implement 3D learning" (O2). Tam was limited by the resources of the school. As he told it, "I have to dig out all the physical apparatus that's like 20 years old for 1999… I'm like, 'Oh wow, these things are old in these this classroom, these stores haven't been touched for 20 years.' So these kids, they never done any real experiment, because the school simply does not supply all the stuff for them to do" (I2). Soon after, the

science department budget was revealed. Panther Park High School presented the information in a meeting where "they literally said the budget for the science department is zero" (O2). Other contextual factors Tam cited for not implementing 3D science teaching and learning into his practice are found in table 4.18. Tam used these factors as reasons to conform to the practice of other science teachers around him.

Table 4.18

Factors that Limited Tam's Implementation of 3D Science Teaching and Learning

Contextual Factor	Evidence
Collaborative Planning	"[3D science teaching and learning] might not work because I have to work with other teachers that are also teaching the same subjects. We have to share material. If I do something differently, they have to change it and make it look the same as me. They might not be able to do it."
Curriculum Pacing	"For physics there's about 8 chapters to cover. We don't have enough time for experiment. We only have enough time to lectures to assignment to assignment and then go experiment? We don't have enough time."
Impact of Pandemic	"3d learnings can only work in regulars time, not the pandemics. There is no theory is to accommodate for the pandemic yet because the student cannot touch the same thing. For example, test tubes. One student from this class go and touch that test tube and another student got to touch that test tube."
Imperfect Learning Environment	"Another challenge I have found out recently is the classroom size and classroom layout. Classroom that are set up with lab tables will be easier to implement ADI labs and 3D instruction. My physics classroom in my current school is rather small and there is no lab table, only desks and chairs, which is a pain to move around every time and can be unsafe for students. I felt that when there are more than 20 students being cramped in a little classroom learning a complex science, instruction will be more difficult."
Lack of Resources	"Once again, funding is a great problems I am having… Certain physic experiment or demonstration that are in the realm of modern physics will require apparatus which can be unaffordable to equip the whole classroom. When these 3D teaching tools are not present, we had to resort back to traditional instruction."

Student Apathy	"From my experience and based on an opportunity to peak into real physic research, doesn't matter how much virtual labs reflect the 3D elements, if those virtual lab programs are not Monte Carlo level of probabilistic physics simulations, then they are truly unauthentic and the students have every right to be bored."

Thinking & Practice

Tam's alienation was revealed through his thinking and practice, particularly around social justice and 3D science teaching and learning. The frustration Tam experienced related to wanting to implement these ideologies exposed how alienation blocked his ability to practice them in the classroom. Tam clearly wanted his practice to align with critical science ideology but felt his context was limited. This can be seen in how frustrated Tam felt towards the school district where he was placed. Tam shared, "How can I implement social justice for these kids? They deserve to have the same education as the other kids in another school... Here's the struggle: If they go into my into my physics class, and I expect them to do the same math as at another school... They can't do it. We have different curriculum… different sequence. Why don't we use the same sequence as another school in high income areas? [The district] going to say, 'Oh, no, these kids can't handle it.' Why do you think they can't handle it? Why don't you let them try?" (I2). Tam recognized how his ability to implement his understanding of social justice in the classroom was limited by the decisions the school district made. Yet, Tam had difficulty recognizing how his decisions in his practice continued his alienation.

In the observations conducted by Mrs. Reid and Mr. Patel, Tam's mentor teacher, a common thread emerged: Tam's own decisions alienated him from his students (Table 4.19). An issue that Mrs. Reid mentioned in every observation was how Tam physically alienated himself from his students. Specifically, Tam would not move around the classroom, staying behind a lab bench, a physical barrier between him and the students.

Table 4.19

Feedback to Tam from Observers centered on Critical Science Ideology

Date	Observer	Feedback Area	Feedback
10/19/2021	Mrs. Reid	Observation Notes: Positive Learning Environment	"Stand at the door and greet the students as they enter. Even if this is not something the regular teacher does, it sets a positive tone for your classroom. Also engage in conversations with the students and form a good rapport with them. It appears that you have done that with some of the student in the front. 'They need to know you care before they care what you know.'"
11/15/2021	Tam	Observation Reflection: Areas for Growth	"I want to work to make the lesson more 3D despite lack of equipment and small classroom layout"
11/30/2021	Mrs. Reid	Observation Notes: Criticality	"I did not hear how you explained the criticality in the lesson. Relating electrical fires or lightening strikes"
2/16/2022	Mrs. Reid	Observed Strengths	"Your rapport with students is much improved. They have more respect for you…"
		Areas for Improvement	"Increase the discussions of Social Justice as you can implement them in your lessons."
3/3/2022	Mr. Patel	Suggestions for Improvement	"Must take time to listen carefully to all students and to acknowledge their contributions"

Date	Observer	Feedback Area	Feedback
3/21/2022	Mrs. Reid	Overall Comments	"You are too comfortable behind that lab table. You must leave and monitor the class throughout the class period… You could have gone into more detail with the issue of 'wheelies/donuts' downtown as that is a social justice issue that is affecting neighborhoods and the economy."
3/31/2022	Mr. Patel	Observed Strengths	"Link present content of K.E and P.E with past and future learning experiences, other subject areas like Math in solving Word problems, and real-world experiences and applications."
		Observation Notes: Learning Environment	"Encourage students answering and discussing when working problems"
4/15/2022	Mrs. Reid	Observations Notes: Positive Learning Environment	"Students are participating much more now and that is to your credit. They and you seem much more comfortable now during the teaching and learning stages of class."
		Suggestions for Improvement	"You still need to break away more from the front of the room. Your tendency to stay behind the lab table."

Through the observations, it is seen that Tam did work to build relationships with several of his students. Even still, Tam's bias towards students who are able to meet his expectations of understanding and applying equations appeared. Tam listed this bias as an area of growth (Table 4.20). At the end of the spring methods course, students completed a professional growth plan. In Tam's plan, he shared both social justice and 3D science teaching and learning as areas of growth for himself.

Table 4.20

Tam's Self-Identified Areas of Growth

Areas for Growth	Description of areas for growth	Evidence
Planning	More emphasis on identities, joy, and criticality components for lesson planning More real-world applications of difficult and concepts	University Supervisor's feedback on lesson plans and observations. Motivation to connect the students to engineering
Instruction	Differentiate and pair students to groups based on mathematical skills Assist students who are English learners and non-English speakers. More emphasis on 3D learning and instruction	University Supervisor's feedback on lesson plans and observations.
Assessment	More experimentation with hand-on assessments Assessments assess both engineering skills and content knowledge.	Observation of mentor teacher's classroom and self-reflection -Students' unsatisfactory scores
Professionalism	More collaboration with other science department members. Reduce personal bias and acknowledge differences among the students.	Lack of involvement with the school faculty members. Personal bias toward more math orientated students

Tam's experience demonstrated how and possibly why science teacher candidates might not implement critical science ideologies in their practice. Tam was alienated within the ITP program through his personal factors and the social character he brought with him. His experience at his placements and fear of drawing attention to himself for teaching differently limited his willingness and ability to use critical science ideology in his classroom.

At the core of this limitation was Tam's ability to recognize and question how his thinking about students, science, and his role as a teacher further alienated him from himself. Unlike Tam, Azula's experience with estrangement from herself led to learning liberation.

Learning Liberation

Brookfield (2005) grounded learning liberation in Herbert Marcuse's work. At the heart of Marcuse's work is understanding how individuals experience and overcome oppression to effect social change. In his work *One Dimensional Man* (1964), Marcuse addresses the concept of one-dimensional thought. Used to control others, one-dimensional thought occurs when people focus on how to make the current systems perform more effectively. To become liberated from one-dimensional thought, individuals must experience an artistic event to "trigger a revolutionary estrangement from everyday life, thus nurturing the tendency to political critique" (Brookfield, 2005, p. 183). Artistic events range from observing a painting to reading text to hearing a piece of music. To participate in the learning task of learning liberation, an adult must experience an estrangement from themselves, which leads to them questioning and altering their actions. After data analysis, it was apparent learning liberation was the least experienced learning task of the seven. Yet, liberation was one of the most prominent codes for Azula. After considering Azula's ITP program experience, it became clear that her personal and contextual factors set her apart from other participants regarding learning liberation.

Personal Factors

Azula entered the ITP program within a year of graduating from the University of Victoria (UV) with a bachelor's degree in biology. Azula "learned science in a very authoritarian environment" (I2). As Azula stated, "The College that I went to is notorious for their science department being slightly ridiculous. [UV] is a great school, but in terms of their science education, it's very intimidating" (I2). The experience Azula had at UV caused her to question if she was in the right field. She reflected, "I was really, really discouraged the first couple of years of my science career. I thought I just didn't know anything, and I didn't know how to learn" (I2). This learning experience was the opposite of what Azula had experienced in the K-12 classroom.

Azula shared, “I was gifted and a straight A student, graduated with a super high GPA and a scholarship out of high school. I got to college and I was like, ‘Am I just dumb? I don't know anything. Was everyone lying to me this whole time?’” (I2). Once she reached her senior level courses, Azula realized, “Oh, I am in the right place. It's not necessarily that I'm doing the wrong thing. It's that the method of how I'm doing it might need to be changed” (I2), which led her to want to become a science teacher. Azula experienced a highly individualized and regimented environment that led her to lose her confidence. This learning experience prior to entering the ITP program primed her to push back on one-dimensional thought about how science should be taught.

Brookfield (2005) described Marcuse’s work as focusing on “the belief we learn our own servitude and that we have learned to love our condition of oppression” (p. 188). Marcuse (1964) wrote the most harmful form of oppression was affluence. Affluence numbs individuals to feelings of dissatisfaction. Being numb to feelings keeps individuals oppressed. During her K-12 school years, Azula was affluent in her education. As a gifted, straight-A student, Azula was exposed to elite science teachers. She reminisced, “I had like a huge love for science in high school because my teachers were so fantastic” (I2). Yet, when she reached college, that privilege evaporated. When a person is engaged in one-dimensional thought, they assume systems work to benefit all. One-dimensional thought does not allow for divergent thinking (Marcuse, 1964). Due to Azula’s science learning experience at UV, she developed a divergent way of thinking about how she was learning science and, later, how she wanted to instruct it. Azula stated, “I think a lot of my science education came from my college years, and it was super intimidating for me. I really hope that I'm not that teacher” (I2). The elements that influenced her learning experience, such as her professors, caused Azula to want to be different for her students.

Contextual Factors

During the first methods course, Azula read two texts that influenced her experience throughout the rest of the ITP program. Each book focused on aspects of social justice and anti-racist teaching. These books brought about questioning, recognition, and action for some participants. For Azula, these texts impacted how she thought about teaching her students science. She wrote, "When entering this program, I did not believe that the HRL framework applied to my teachings – history teachers were the people I saw as 'in charge' of the history conveyed to students (Muhammad, 2020). I quickly learned that the HRL framework is not solely based in what we consider formal history education. This framework is the basis for how we build our classrooms, how we communicate with our students, and how we frame our lessons to make sure that all of the individual lives we are influencing are given relevant information" (R2). Azula carried this thinking with her as she entered her placement. Azula's placement was at her former high school, Palomino High School. At the beginning of practicum, Azula completed an assignment that required her to analyze data related to Palomino High. Through this assignment, Azula was "able to see the race divide" (I2) concerning special education and discipline. She found many students who were disciplined also required accommodations and were not White. This was "very eye opening" (I2) for Azula and led her to question what was happening at Palomino. That assignment and the two texts caused Azula to alter her actions in the classroom and critique her district.

For Marcuse, social change begins with the individual. He believed "it is the primary experience itself which must change radically if social change is to be radical, qualitative change" (1972, p. 62). This primary experience is one of liberation. Marcuse offered a way for individuals to overcome oppression through liberation. The process of liberation begins when

one is either isolated or experiences a thought-altering piece of art. This is a change from other critical theorists who may have thought of art as elitist (Brookfield, 2005). Marcuse focused on art due to the "chance of breaking with the familiar, of inducing in us an awareness of other ways of being in the world" (Brookfield, 2005, p. 201). In Azula's case, the texts she read in her first methods course were the art that altered her experience of the world. She provided an example of how these pieces of art impacted her thoughts and actions. Azula shared, "I have a table in my seventh period that's extremely chatty…to the point where they're not listening to my instructions and are not doing the work. I have specifically noticed that a Black female is at that table. My blame immediately wanted to go to her for like talking. I'm like, 'It might not be her. I'm not standing there the whole time. I'm not noticing that.' I don't want to take that attitude as an issue... I moved someone else from the table. It ended up being that person that I moved. It's small things like that… where I'm able to socially recognize there are issues happening and then be culturally aware" (I3). Azula's experience with art during her ITP program directly impacted and altered her way of engaging with her students.

Thinking & Practice

Azula continued demonstrating how she learned liberation through her thoughts on what it means to be a science teacher. A change in how Azula thought of her role as a teacher can be seen in the language she used to describe her thinking. During the study, I asked each participant, "How would you describe your role as a teacher?" This offered the opportunity to observe how their responses shifted or stayed the same over time. Azula's responses are found in Table 4.21.

Table 4.21

Azula's responses to "How do you describe your role as a teacher?"

Interview Date	Response
June 2021	I want to allow my students to actually enjoy education and learning… Education is like a lifelong thing. I think just being able to kind of inspire that in them to be like, "Hey, listen, scholarship is not something that's limited to a few people. Scholarship is something that literally anyone can achieve and that everyone should achieve." …I think it's just allowing them to understand that learning is not just part of the classroom. Learning is something you should always allow yourself to be open to.
August 2021	It's not only to facilitate education between content and my students, but it's also to answer questions around science. I'm here to answer your questions about being successful in life. A lot of students look up to their teachers, and they're like, "Okay, this is my role model." … I think I'm definitely there as a mentor, a facilitator, a friend to an extent. We have to keep our boundaries, but I still want to be their friend. Just a responsible adult in their lives, because not everyone has that responsible adult.
January 2022	I definitely think first and foremost as a mentor more than anything. My job is to deliver content in an effective way where my students are able recall and apply the information. I feel that social connection is so important in order for that knowledge to actually stick … I've noticed that having a teacher that they care about, makes them want to do things. I definitely think that it's important to have that social relationship with your students.
May 2022	I think… not only just a source of information for students, but also someone who is well qualified to present that information in ways that are applicable to students… because we dive so deep into equality, justice, diversity within our classes, I feel I'm well prepared to be that spokesperson for my students. Not only just an instructional lead, but also a spokesperson and an advocate for their needs, for their wants, for the things they're able to accomplish… I have the role of a learner. I have the role I have an instructional lead. And then I also have the role of a mentor and a spokesperson.

In June, Azula's responses focused on how she supported her students in understanding that learning is a continual action. This differs from her response in May, where she focused on being an advocate, spokesperson, mentor, instructional lead, and learner. In her May response, Azula attributed her ability and awareness to be a spokesperson for her students to her alignment with social justice in the classroom. This is supported by a reflection response Azula constructed.

She wrote, “At first, being an abolitionist educator simply meant being aware of the social happenings that influence my children of all backgrounds and races. Cultivating genius was its own concept, but making sure that my students felt seen and heard as individuals with impactful histories. After teaching some incredible students from different races, religions, and ethnicities for two semesters, I can confidently say that genius stems from abolitionism. The two are completely interconnected in my teaching style, and that is a change that I did not expect to occur” (R3). Azula’s liberation from her previous way of thinking about how science should be taught and her role as a teacher presented itself in her practice.

In order to determine how Azula’s shift in thinking appeared within her practice, I analyzed her field performance observations conducted by Mrs. Reid. I chose to focus on the knowledge of the learner and identity development indicator because of its attention to the teacher candidate’s awareness of their students' cultural and community strengths, needs, and experiences (Figure 4.6).

Figure 4.6

Knowledge of the Learner & Identity Development Indicator from the Observation of Field Performance Rubric

	INDICATOR	*Advanced*	*Proficient*	*Developing*	*Insufficient*
	PROFESSIONAL KNOWLEDGE				
1-PK	**Knowledge of the Learner & Identity Development: Builds upon learners' existing academic, developmental, linguistic, personal, cultural/community strengths, needs, and experiences. (Including, but not limited to, race, ethnicity, language, religion, socioeconomic status, gender, sexual orientation/expression, national origin, and/or exceptionality.)**	Maximizes learner's prior knowledge by integrating lesson objectives with learners' academic, personal, developmental, linguistic, **AND** cultural/community strengths, needs, **AND** experiences.	Uses learner's prior knowledge by integrating lesson objectives with learners' academic, personal, developmental, **AND** linguistic, **AND/OR** cultural/community strengths, needs, **AND/OR** experiences.	Uses learner's prior knowledge by integrating lesson objectives with learners' academic, personal, developmental, **OR** linguistic, cultural/community strengths, needs, **OR** experiences.	Does not use learner's prior knowledge by integrating lesson objectives with learners' academic, personal, developmental, linguistic, **OR** cultural/community strengths, needs, **OR** experiences.

This indicator pays particular attention to how teacher candidates incorporate identity building within their lessons. For a science teacher candidate to be proficient, they need to be able to

question and align their actions towards critical science ideologies. In Table 4.22, Azula's scores demonstrate her exploration and work towards liberation from her previously held ideologies about science education.

Table 4.22

Scoring on Knowledge of the Learner & Identity Development Indicator for Azula Conducted by Mrs. Reid

Participant	Fall 1	Fall 2	Spring 1	Spring 2	Spring 3
Azula	Advanced	Proficient	Proficient	Advanced	Advanced

Azula's journey to and time within the ITP program both drove her awareness of the oppression that surrounded her within the education system. The texts Azula engaged with supplied her with the words and experience to alter her thinking about what it means to teach science. Liberation is a continual process that ultimately leads to political and social change. Azula's changes in her thinking about students different from her and what she had to offer demonstrated her work towards social change. Through her personal and contextual factors, Azula revealed how she was learning liberation and enacting it in her classroom. As much as Azula learned liberation, Jacob also engaged in learning democracy.

Learning Democracy

For this learning task, Brookfield (2005) looks to two adult learning theorists: Eduard Lindeman and Jürgen Habermas. Lindeman's work focused on understanding the role democracy had in adult education. While Lindeman is often associated with pragmatism and not critical theory, Brookfield (2005) draws on his work due to Lindeman's analysis of how democracy influences adult education. For this study, I used Brookfield's (2005) definition of democracy based on Lindeman's work. Democracy is when adults can "deal respectfully with difference,

live with unresolved conflict, and accept that proposed solutions to complex social problems should always be viewed as temporary, as contingent" (Brookfield, 2005, p. 61). Habermas, a critical theorist, also focused on democracy, specifically in discourse theory. Brookfield (2005) merged their work to develop the critical adult learning task of learning democracy. To participate in learning democracy, an adult must learn "to live with ambiguity and contingency as much as learning how to apply deliberative decision-making procedures" through communication with others (Brookfield, 2005, p. 269). After coding, Jacob emerged as the one participant who strongly engaged in this learning task. Jacob's personal and contextual factors set him apart and primed him for participating in learning democracy compared to other participants.

Personal Factors

The ways adults participate in learning democracy within formal educational settings are varied. Students may work together to form norms in the classroom, negotiate activities, participate in discussions with others with different points of view, and engage in critical reflection. The task of critical reflection and what this means for learning democracy is where Jacob is set apart from his peers. This activity is rooted in the development of moral consciousness, as outlined by Habermas (1990). The level at which moral consciousness comes into being depends on an adult's ability to detach themselves from their usual way of thinking and act in a way that is not predetermined by their current ideologies. This happens when an adult is "aware of life's contingencies, by her recognizing the contextuality of beliefs, and by the ability to understand that thought is ideologically shaped" (Brookfield, 2005, p. 257). Awareness, recognition, and understanding form through communicating with others who have

different experiences of the world. When Jacob entered the ITP program, he brought this ability with him.

Jacob shared that he "studied abroad in my undergrad. I did spend like six months in Thailand and did a bunch of research with elephants… And I completely changed my mind about my life" (I1). At 26, Jacob was the third eldest participant in the study but had worked a variety of jobs. From being a veterinarian technician to a bartender to a zoo keeper, he interacted with many different people through his jobs. These diverse experiences in life provided the opportunity for Jacob to become aware of the oppression and domination of various systems in life. An instance of how Jacob engaged in learning democracy was found in one of his final critical reflections. He stated, "Love talked about her childhood and the struggles of growing up black and it really opened up my mind to things that I have never experienced as a white male. I reflected on the education survival complex and spirit murdering, and how those experiences are so different from what I experienced… They have helped me recognize my privilege further than I ever have before" (R3). In this example, Jacob listened and suspended his judgment of Bettina Love's (2019) experiences communicated in her text. He then compared it to his life experience to assist him in understanding the privilege bestowed upon him by society. This depth of critical reflection would not be possible without a developed moral consciousness. Jacob's willingness to reflect critically demonstrated his dedication to continuous learning about himself and the systems he functions within.

Contextual Factors

A key assumption made when discussing learning democracy is adults are continuously learning. Brookfield (2005) drew upon Habermas' (1975) thoughts about the learning adults experience. The main types are nonreflexive and reflexive learning. Nonreflexive learning is not

critical and occurs when an adult learns not to resist the dominant culture (Habermas, 1975). Reflexive learning is critical. This type of learning happens when adults question and challenge the status quo through communicating with others who have different perspectives (Habermas, 1975). An aspect of reflexive learning is evolutionary learning. This type of learning must take place for an adult to learn democracy. Evolutionary learning brings about shifts and changes in how individuals function within systems that lead to societal development (Habermas, 1975). Two conditions must happen for evolutionary learning to take place: (1) there must be an unresolved systemic issue present, and (2) an individual has learned about the systemic issue but not had the opportunity to take action in the system (Habermas, 1975). One systemic issue Brookfield mentions is racial tensions. Jacob experienced this secondhand while at his placement in River Mill Middle School.

Jacob described the situation: “There's a teacher at our school right now. She’s the only other White teacher at the school, and she has students call her racist all the time. It really bothers her, which is understandable, but she doesn't implement [anti-racist teaching] into her class. When you're disciplining young students of color, and you're an older White person, they're just like, ‘Okay, well, you're racist.’” (I2). Through such observations, Jacob developed a more profound sense of how the dynamics of the school system maintained racial tension. This led him to challenging and questioning how students are taught and the need for social justice in the classroom. Ultimately, Jacob decided to shift and change his thinking, and therefore his practice, to better meet the needs of his students rather than maintain the status quo. Jacob reflected, “I will confront my whiteness and do what I can to be an ally to students of color. I will understand the history of our country and education system and use that to guide my decisions rather than ignore them and pretend those things never happened” (R3). Jacob was

placed in a unique context for a White man. He was a minority in a school that served students from traditionally underserved communities, which provided Jacob the opportunity to engage in not only reflexive learning but also evolutionary learning toward democracy.

Thinking & Practice

Jacob manifested this learning task through his ability to use differences in his classroom to his advantage while understanding there are many unique ways to address inequity in his practice. A major concern for him was connecting with students in a genuine way that encouraged them to learn science. He found his answer to this concern by using critical science ideology in his practice. Jacob conveyed such thinking when he stated, “I will build relationships with every student and make sure that they feel heard and seen and help them understand that they matter, and they are capable of anything that they want to achieve” (R3). Jacob determined how to “create a learning environment where students are truly heard and respected, but also taught how to resist, protest, and struggle against the many injustices ingrained in our society. Lastly, and in my opinion the most important part, abolitionist teachers must create an environment where students can find joy” (R2). In order to do this in the science classroom, Jacob thought of his instruction like a band or gym teacher. He wanted to “teach science in the same way gym teachers teach gym and band teachers teach band. When you go to gym, you're not writing on a sheet of paper how to run, you're just running. When you go to band, you're not like, ‘This is how this instrument works.’ You're learning how to play that instrument” (I1). Along with making his classes student-centered, Jacob aimed to alter students’ perceptions of science. He believed, “In American schools, a majority of theories and laws and any early understandings of science that we build upon today are just White guys. If you're not a White guy, it’s like, ‘I can't do that, because I'm a girl or I'm a person of color.’ It's not a direct, like,

'Oh, yeah, this isn't for you.' When you're only bombarded with stuff that has been done by people who aren't like you, it feels inaccessible" (I2). To see how Jacob's thinking about critical science ideologies appeared in his practice, I analyzed his observations by Mrs. Reid. I focused on the learner engagement indicator (Figure 4.7) from the observation rubric.

Figure 4.7

The Learner Engagement Indicator from the Observation of Field Performance Rubric

INDICATOR		*Advanced*	*Proficient*	*Developing*	*Insufficient*
INSTRUCTIONAL DELIVERY					
1-ID	**Learner Engagement: Engages learners in active learning by developing higher order, critical/creative thinking through inquiry-based learning promoting diverse perspectives/experiences.**	Engages learners in active learning by developing higher order, critical/creative thinking through inquiry-based student-centered learning **AND** promotes diverse perspectives/experiences.	Engages learners in active learning by developing higher order, critical/creative thinking through teacher-facilitated learning **AND** promotes diverse perspectives/experiences.	Directs learners to acquire knowledge **AND** skills through teacher-directed learning.	Directs learners to acquire knowledge **OR** skills through teacher-directed learning.

This indicator pays particular attention to how student-centered a lesson is and how students are provided diverse opportunities. In Table 4.23, Jacob's scores demonstrate his consistent growth in the fall semester. He reached the highest level of advanced for the entire spring semester.

Table 4.23

Scoring on Learner Engagement Indicator for Jacob Conducted by Mrs. Reid

Participant	Fall 1	Fall 2	Spring 1	Spring 2	Spring 3
Jacob	Developing	Proficient	Advanced	Advanced	Advanced

Jacob grew in his ability to view education and the world from others' perspectives through his aptitude and willingness to step out of his typical frame of reference. Jacob's thinking and practice were aligned with critical science ideologies so that he could practice democracy in his classroom. The depth at which Jacob experienced this was impacted by his personal and contextual factors that were unique to him.

Closing the Cases: Researcher's Reflection

The interactions, data collection, and learning with all five participants spanned 11 months and an entire ITP program. Spending approximately a year together in methods classes, their time in their placement classrooms, and dedication to completing their assignments in the ITP courses encompasses an immeasurable amount of effort towards becoming the science teachers each participant envisioned for themselves. We each put more time and energy towards our interactions through this study than initially planned, but we were all invested in engaging in the process. I am grateful for Azula, Jacob, Madelia, Starr, and Tam's insights and knowledge. The experiences shared here reflect the variety of learning moments science teacher candidates live through in ITP programs. None of their experiences were the same, yet commonalities exist, especially regarding how their personal and contextual factors influenced their alignment or resistance to critical science ideology in their practice. In the following chapter, I discuss the thematic findings and conclusions of this study.

5 DISCUSSION

Science teacher candidates (STC) enter an initial teacher preparation program with ideas of what it means to be an educator (Russel & Martin, 2023). Yet, they encounter ideologies about science education for all students that often differ from what they know (Arellano et al., 2016). This study explores how science teacher candidates respond to the ideologies of social justice and 3D science teaching and learning. When presented as one ideology, these ideas lead science teacher candidates to implement critical pedagogy. Teachers who use critical pedagogy seek to help students develop their identities, utilize community resources, and work to co-construct knowledge and action with students (Arellano et al., 2016). Teacher candidates encounter an ideology that asks them to question how their instruction and curriculum help students understand themselves, others, power, equity, and anti-oppression (Muhammad, 2020). STCs' ideologies around what should and should not be discussed in the science classroom may be challenged.

Purpose Statement & Research Questions

Learning to teach secondary science under NGSS requires teacher candidates to become fluent in the three dimensions of crosscutting concepts, core ideas, and science practices. It is important to note a key critique of the NGSS is how its focus on "equitable" actually means "accessible" (Hoeg & Bencze, 2017). The lack of clarity makes it easy for social justice and equity to become invisible within the NGSS (Rodriguez, 1997). This is one of many reasons why critical pedagogy is not often seen in science education (Arellano et al., 2016). Yet, in order to teach science to all students, critical pedagogy must be employed in the classroom. While in ITP programs, teacher candidates began reflecting on their own experiences as students to reevaluate their understanding of what it means to teach science. This questioning and development of

pedagogical identities can potentially cause a shift in ideologies around science education. The purpose of this study is to explore why science teacher candidates align and/or resist critical science education ideologies while in an initial teacher preparation program. Guiding this research are the following research questions:

1. Why do secondary science teacher candidates align and/or resist critical science ideologies?
    a. How do personal factors of teacher preparation influence teacher candidates' shift with critical science ideologies?
    b. How do contextual factors of teacher preparation influence teacher candidates' shift with critical science ideologies?
2. What role does shifting ideologies have in secondary science teacher candidates' willingness to implement new instructional strategies in their classrooms?

Major Findings

This section highlights a significant finding related to each research question. First, I answer how personal factors influence science teacher candidates to align or resist critical science ideologies. Then, the second finding focuses on contextual factors and their role in science teacher candidates' alignment or resistance to critical science ideologies. The last finding relates to how science teacher candidates shift their practice to align with or resist critical science ideologies.

The consistency with which science teacher candidates' prior learning experiences are addressed in the ITP program influences their willingness to align with or resist program ideologies.

Not surprisingly, science teacher candidates' prior learning experiences influence their thinking about the ideologies presented to them in ITP programs. Tom Russell and Andrea K. Martin (2023) highlight how unaware science teacher candidates are of how much they have learned about teaching through observing their instructors. They claim, "How individuals learn from experience remains a poorly understood phenomenon" (Russell & Martin, p. 871, 2014). This finding is a response to this claim. The experiences of Starr and Tam demonstrate how science teacher candidates align with or resist critical science ideologies based on their prior learning and how consistently their prior learning is refuted during their ITP program.

In reclaiming reason, Starr's assumptions about how to best teach science with a focus on implementing group work were highlighted. Starr shared she was introduced to group work during the ITP program. Starr ultimately shifted her thinking and practice to include small group work in almost all her lessons. Her instructional strategies included stations, lab investigations, and group activities constructing models. The changes she saw in her students influenced the modifications in Starr's practice. Not only did the feedback from her students influence Starr's thinking, but she was also consistently exposed to thinking around group work from her mentor teacher, university supervisor, and methods course instructor. Rarely did Starr experience a methods course where some form of group work was not incorporated. She also received monthly feedback from her mentor teacher, Mr. York, and university supervisor, Mrs. Reid, who consistently focused on group work.

In contrast, Tam demonstrated how prior learning experiences, when reinforced, lead to a stronger draw towards resistance of critical science ideologies than alignment. In overcoming alienation, Tam's experience in the ITP program highlights this tension. Tam's prior learning experiences where he faced inequality drove his thinking about social justice and how to best provide it to his students. Tam's coming of age in Vietnam, immigrating to the United States at 14, moving through high school while learning English, and then expanding in his undergraduate program brought forth the struggle and inequity Tam felt. At the end of the ITP program, Tam reflected that he needed to focus on both social justice and the dimensions of 3D science teaching and learning in his practice. The evidence he cited for these areas of improvement was only from his university supervisor's feedback. Yet, when I reviewed his lesson plans and field performance observations, there was little consistent feedback to Tam centered on social justice. Tam mentioned in contesting hegemony that his mentor teacher struggled to meet the expectation of incorporating social and emotional learning into his lessons. The inconsistency in feedback focused on social justice allowed Tam to reinforce his prior learning experiences rather than challenge them towards more sophisticated thinking and practice of social justice in the science classroom.

The experiences of Starr and Tam reflect what is seen in the literature regarding science teacher candidates enacting their shifting or reinforced learning (Bullough et al., 1992; Feiman-Nemser & Buchmann, 1985; Kang, 2008). Science teacher candidates will align or resist the ideologies presented in an ITP program based on their prior learning experiences. Kang (2008) focused on the epistemologies of science teacher candidates and how they shifted throughout a methods course. Their study found there was shifting of epistemologies from naive towards sophisticated, but they were unable to determine what caused the shift. In this study, participants'

prior learning experiences either primed them for alignment with critical ideologies (Starr) or reinforced their existing views (Tam). The consistency with which participants were receiving feedback from their students, mentors, and participating in activities highlighting areas of improvement encouraged them to question and reflect on their actions. When feedback was inconsistent or non-existent, participants found reinforcement for their current thinking. Keonghee Tao Han and colleagues (2015) examined how teacher candidates in rural and urban contexts implemented critical pedagogy. They found students in the rural ITP program actively resisted critical pedagogy. While the more diverse teacher candidates in the urban ITP program came to be more accepting of critical pedagogy, they still displayed only a surface willingness to accept social justice curriculum. Tam's placement was in an urban context, while Starr was in a more rural school system. Starr aligned with critical science ideologies, while Tam was less aligned. These findings suggest that prior learning experiences and ITP program interventions, rather than geographical location, influence teacher candidate alignment with critical science ideologies.

Ajayi (2017) studied how preservice teachers thought of their ITP program and their willingness to implement social justice into their practice. Her findings revealed that while teacher candidates professed an understanding of the need for social justice in the classroom, they did not practice it. While the preservice teachers experienced activities in their ITP program that supported their understanding of social justice, they did not have their prior learning experiences addressed. The activities focused on the K-12 students' cultures and communities, but they did not address the needs of the teacher candidates. This study demonstrates the importance of attending to teacher candidates' prior learning because, without it, their ability and willingness to implement social justice in the classroom is limited. The participants of my study

were continually faced with their prior learning in the methods courses but not as consistently in their placement. This finding demonstrates the importance of challenging ideologies. Brookfield (2005) stated this critical learning task is preeminent to all others. As seen in the studies above, if teacher candidates are not consistently provided opportunities to challenge both their own ideologies and the ones put forth by their program, their willingness to align is limited. This is not the only significant element of understanding why teacher candidates align or resist critical science ideologies. Another broad finding suggests the contextual factor of a teacher candidate's placement is also instrumental.

When placement schools' ideologies do not align with the ITP program, science teacher candidates are consistently positioned to critique their understanding of critical science ideologies.

The "two-world pitfall" or the disconnect between ITP programs and placement school contexts is not a new idea (Feiman-Nemser & Buchman, 1985). Melissa Braaten (2018) explored this phenomenon further with science teacher candidates. Through her study, she found that science teacher candidates still work to negotiate their experiences and learning in both worlds while facing contradictions in ideologies and thinking. Braaten (2018) examined, in particular, the role of the mentoring relationship science teacher candidates form with their mentor teacher. Mark Windschitl et al. echoed her findings about practicum (2021). They confirmed what many teachers who have experienced practicum know: not every teacher candidate has the same opportunity to practice teaching. In their study, Windschitl et al. (2021) found that 60 percent of their 65 participants were placed in classrooms where the pedagogy reflected teacher-centered and non-reformed science teaching practices. The second finding from this study focuses on school culture and the affordances and limitations they provided participants in critiquing their

understanding of critical science ideologies. The experiences of Azula and Madelia demonstrate how science teacher candidates are positioned to critique their own understanding of critical science ideologies.

Azula's experience with contesting hegemony and learning liberation is rich with examples of how she was positioned to critique her thinking about critical science ideologies. Azula's placement was at her former high school, Palomino High School. At the beginning of practicum, Azula completed an assignment that required her to analyze data related to Palomino High. Azula was "able to see the race divide" concerning special education and discipline through this assignment. She found many students who were disciplined also required accommodations and were not White. This was "very eye-opening" for Azula and led her to question what was happening at Palomino. This information led Azula to unmask power in the education system, such as statistics focused on disciplinary actions, socioeconomic status, racial demographics, and accommodations for students in her district and placement school. As her time in her placement progressed, Azula began to hone her classroom facilitation style. While developing this, she used her knowledge from readings in her ITP program to alter her thinking. Azula found herself questioning her thinking and assumptions about students based on racial stereotypes, particularly in classroom facilitation. Azula recognized she was experiencing a shift in her thinking and going through a process of change. Her positioning as an authority in the classroom pushed her to critique her motives and shift closer to aligning with critical science ideologies.

Like Azula, Madelia was positioned as an authority figure rather than a student in her placement. This positioning revealed a side of the education system to Madelia that was new to her. As discussed in unmasking power, Madelia recognized how the educational system uses

repressive power to maintain the status quo. Madelia quickly began to think critically about how power and control were used in her placement to consistently oppress students. For instance, she noticed a shift in her thinking around dysregulated student behavior. Madelia's primary focus became wanting to know how to better support the student rather than ensuring the student experienced consequences for their behavior. Being in a position of authority allowed Madelia and Azula to critique and enact their understanding of critical science ideologies while at their placement.

The way the mentor teacher views their role during practicum can often impact the experience of teacher candidates (Matsko et al., 2018; Ronfeldt et al., 2018; Stroupe & Hancock II, 2022). Azula and Madelia professed to have positive relationships with their mentor teachers, but both readily admitted they did not observe critical science ideologies in their placement classroom. Masha Izadinia (2015) found the relationship between mentor teachers and teacher candidates impacts the confidence of teacher candidates in the classroom. Teacher candidates who lack a rapport and personal connection with their mentor teachers are less likely to reflect on their practice and accept new pedagogical challenges, such as trying a new instructional strategy (Izadinia, 2015). In contrast, those with positive experiences with their mentor teacher often feel like teachers at the end of their practicum by having a sense of authority in the classroom (Izadinia, 2015). The positive relationships Azula and Madelia experienced with their mentor teachers gave them the confidence and freedom to position themselves to enact and critique critical science ideologies. Due to their confidence, they felt safe to contest hegemony in their actions. Their mentor teachers also positioned them as persons of authority in the classroom, which gave them space to reflect on their thinking. As individuals with more power in the classroom, Azula and Madelia began to unmask their own power and noticed the power their

students held in the learning process. By being positioned to reevaluate their thinking and enactment of critical science ideologies, participants were given space to reason and determine what they valued in their practice.

ITP programs that are grounded within critical theory have four principles: (1) an explicit focus on justice and equity, (2) opportunities to learn about out-of-school factors that shape learning, (3) opportunities to unpack assumptions about identity, teaching, and learning, and (4) specific teacher and relational practices that center students and communities (Hammerness et al., 2023). By these criteria, the ITP program of study is considered grounded in critical theory. All five participants were in courses that challenged them to think about and face broader societal issues that impacted their students and, potentially, themselves. By becoming aware of these issues, participants could begin to challenge their ideologies, unmask the powers behind them, contest hegemony with their decisions, and ultimately reclaim reason to determine what they value in the classroom. This would not have been possible if teacher candidates did not interrogate how dominant ideologies appear in the science classroom. Carter Andrews et al. (2019) determined that if teacher candidates do not question their assumptions, motivations, and needs within the education system, districts, schools, departments, and classrooms, inequities can persist unintentionally. Azula and Madelia each showed a questioning and a challenging their own thinking and actions in the classroom throughout the ITP program. This continual pushback drove them to further align with critical science ideologies.

Teacher candidates combine the ideologies of social justice and 3D science teaching and learning into one through their own reasoning and practice.

NGSS aims to shift instruction in the science classroom to position all students as doers of science instead of listening and receiving information from their teacher (Miller et al., 2018).

Emily Miller and colleagues (2018) outline four reasons why shifting toward this type of science classroom is difficult. First, the power structure in the classroom traditionally implies the teacher is the sole holder of content and pedagogical knowledge. Secondly, students have different epistemic positions about each other due to entrenched social and political systems. Third, NGSS has been applied to larger systems and structures of schooling that include factors of resistance to reform and time. Lastly, the definition of science and what it means needs to be addressed completely in the classroom rather than continuing to perpetuate falsehoods, like the scientific method (Miller et al., 2018). Some of these struggles were present in the experiences of my study participants. Tam found himself reluctant to let go of the traditional role as the sole knowledge holder in the classroom. Azula was limited in how she was able to implement critical science ideologies due to her district, school, and department's expectations towards courses with standardized tests. When tackling these challenges, major ideological shifts must occur for science teacher candidates, particularly since they were not taught science in this way. In addition to learning to instruct a student-centered classroom, teacher candidates are expected to employ social justice or critical pedagogy in their practice. Traditionally, this has been a difficult shift and way of practice for teacher candidates (Goodwin & Darity, 2019). The experiences of Starr and Jacob demonstrate how participants combined the ideologies of social justice and 3D science teaching and learning into one through their reasoning and practice.

Starr wanted to align with critical science ideologies but struggled to determine what that looked like in practice. Reclaiming reason outlined her experience with this. The process of aligning and blending ideologies began with confronting her assumptions about how students best learn biology. Starr felt the tension of trying to teach in a way she herself was not taught, specifically towards implementing culturally relevant pedagogy. Starr recognized causality in

how her students learned content and related it to their lives. Her students were able to retain and make sense of complex ideas when they could relate a phenomenon to their lives. She quickly came to value making her content relatable to students. Starr found using particular instructional strategies, such as open-ended questions, provided students the opportunity to connect their sense-making to their own cultural experiences. Starr's ability to recognize the causality between how she taught her students and their ability to learn science best emerged from her acceptance of the ideologies of social justice and 3D science teaching and learning. By recognizing and acknowledging her students' cultures and experiences, Starr incorporated strategies to support them in believing they matter to her (Love, 2019). Starr blended these strategies with 3D science teaching and learning to include phenomena related to students' lives and identities.

Jacob's movement towards aligning and combining social justice with 3D science teaching and learning began with his planning process. He experienced a shift in his thinking that resulted in a change in priorities while planning. Jacob realized grounding his lessons in social justice supported implementing aspects of the three dimensions naturally. Because of this, his lesson flowed and made connections in a meaningful way. The shift in his thinking that appeared in his planning made it easier for Jacob to teach in the way he envisioned. Jacob thought of his instruction like a band or gym teacher. He wanted to have students practice science, as they would practice their instrument in band class or running the mile, rather than seeing or hearing how to do science. He found grounding his lessons in critical science ideologies allowed him to teach the way he envisioned while supporting all of his students.

Participants began to combine both ideologies in either the summer or the fall semesters of their ITP program. Carmen Mills (2013) followed two teacher candidates through the final two years of their ITP program. She found each participant shifted in their understanding of

providing equitable education to their students. From wanting to treat every student the same to realizing every student is unique occurred because the teacher candidates could reflect on their practice and their students. Mills (2013) asserts each teacher candidate experienced a shift in their views around critical pedagogy at the same time in their program: the end of their first year. Mills (2013) attributes this shift to developing their teacher identities due to having been in the classroom. The finding of this study pushes back on Mills (2013) study result. Participants began to shift their views around social justice before entering the classroom. They also developed this aspect of their thinking as a teacher at different times in their ITP program, as seen with Jacob and Starr. While Mills (2013) study is not examining ideological shifts, she is addressing practice. As seen in the evidence above, participants worked to make sense of what critical science ideologies looked like in their classrooms. Still, Starr and Jacob had already shifted their thinking and practice toward critical pedagogy in their first semester. This mimics the other teacher candidates in my study.

Participants in the study were primed in the first methods course to begin combining social justice with the three dimensions of science teaching and learning. From the first day of class, students explore key concepts in social justice through texts. This harkens back to Felicia Mensah Moore's (2009) work with a book club with science teacher candidates that focused on an ethnography, *Ways with words: Language, life, and work in communities and classrooms* by Shirley Brice Heath (1983). Students were placed in groups and discussed parts of the book with their groups in class using open-ended questions provided by Moore. Initially, Moore's (2009) students viewed multiculturalism and diversity issues as irrelevant to science and their teacher preparation, but after the book club, they viewed these issues as highly relevant to their preparation as science teachers. The learning that occurred in the book club is similar to what

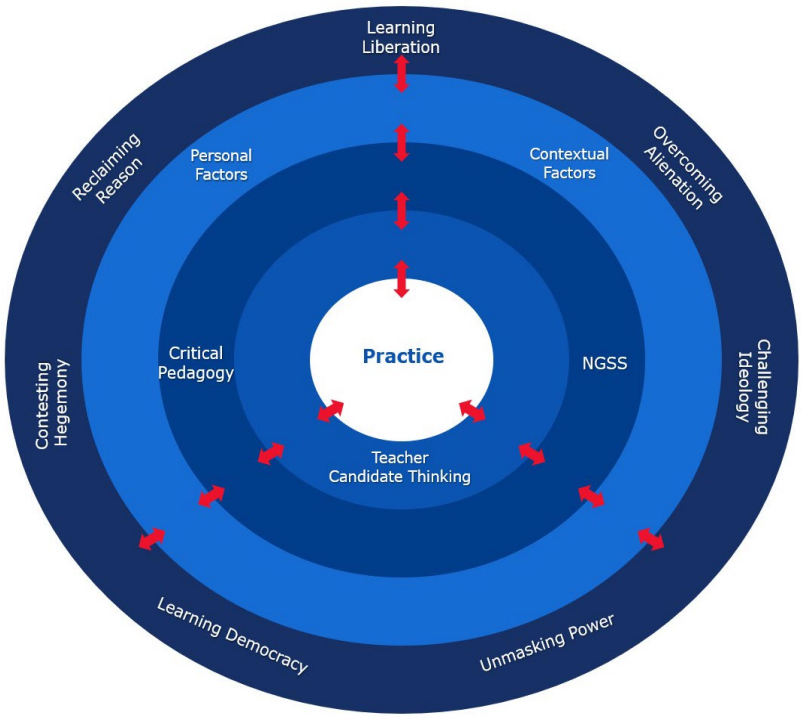
occurred for participants before being exposed to 3D science teaching and learning. By reclaiming reason, participants determined they valued social justice but needed a way to demonstrate it. When they entered the classroom, they did not observe these ideologies in practice (Duckworth & Maxwell, 2015). Yet, when teacher candidates taught their first lesson in the classroom and received student feedback, it encouraged them to combine and further align with critical science ideologies.

Critical Learning for Systemic Reform Model

The critical learning for systemic reform (CLSR) model was first proposed in chapter one and further explored in chapter 2 (Figure 5.1). This model moved inward from critical learning tasks towards practice while connecting the different ideologies and aspects from the teacher-centered systemic reform model.

Figure 5.1

Original CLSR Model

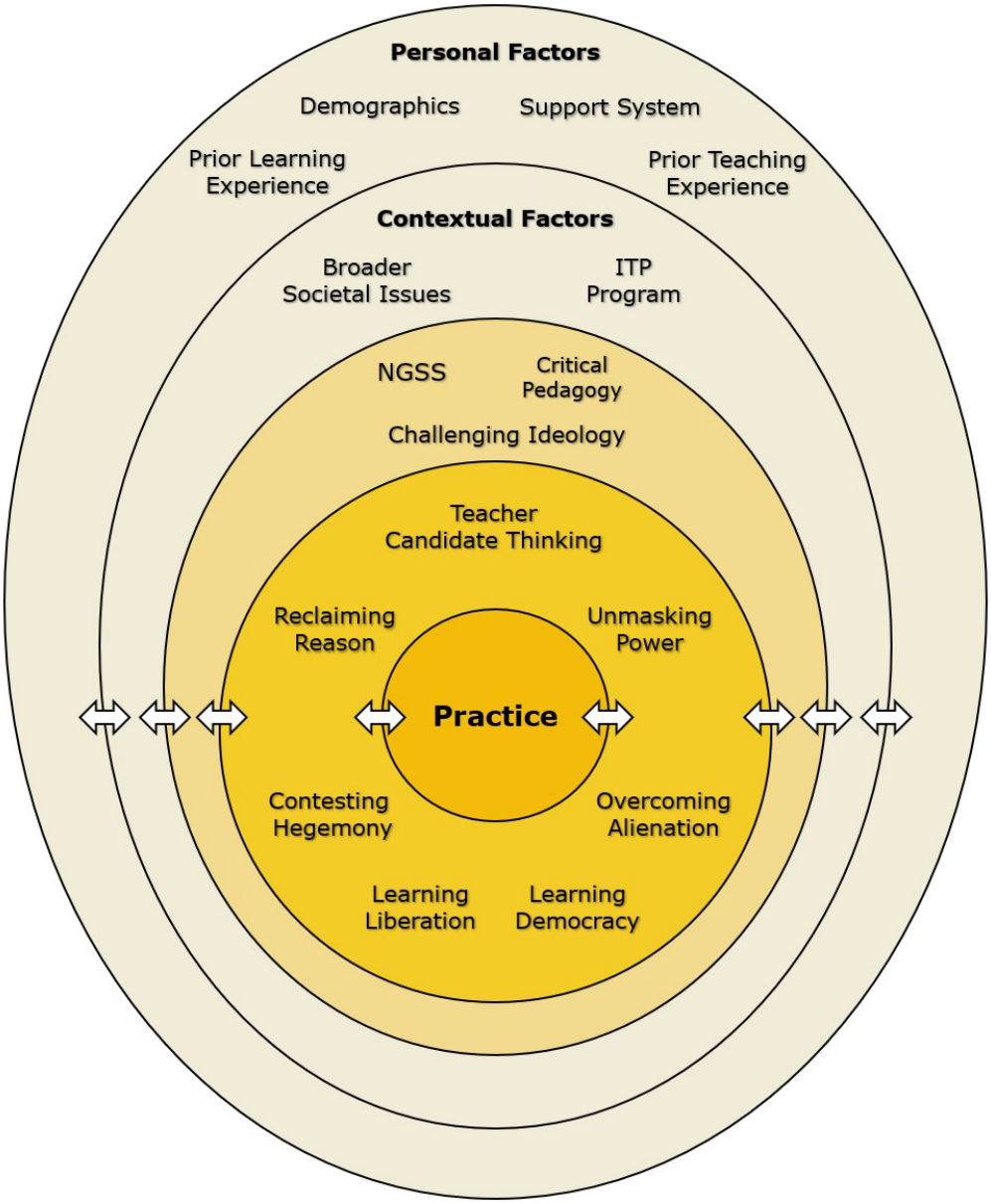


Throughout this study, I referenced the original model. Yet, during analysis, it became clear I needed to reconsider the structure of the model. At the beginning of this study, I described the model as a cheesecake with each section forming a layer and practice cutting through each layer like a fork. I placed the critical adult learning tasks from Brookfield (2005) together in one ring because the "learning tasks are, of course, interrelated, and any separation of them is mostly for analytical purposes" (p. 39). I then include the personal and contextual factors together as I supposed they would be influenced by the critical adult learning tasks, but also an individual's interaction with the two ideologies proposed by the ITP program. These ideologies would impact a teacher candidate's thinking, which would appear in their practice. My understanding and thinking about the CLSR model has changed since analyzing Azula, Jacob, Madelia, Starr, and Tam's experiences in the ITP program.

Key aspects of the final version of the CLSR model have stayed the same (Figure 5.2). Practice is still at the heart of the model. It is here where the work science teacher candidates do to make sense of their experiences, thinking, and observations reveals itself. The placement of teacher candidates' thinking and the ideologies proposed by the ITP program has not changed, but elements of critical learning have been added to those sections to better represent the evidence from my participants' experiences.

Figure 5.2

Final CLSR Model



The changes to the model are extensive, starting with the outside layer. Originally, all of the critical adult learning tasks made up the outside layer of the model. Now, personal factors dictate the learning experience science teacher candidates have towards critical learning for systemic reform. This change was pivotal in representing the experiences of all participants. For instance, the single case studies of Azula, Tam, and Jacob illustrate how personal factors worked to

determine how individuals engaged with their critical learning throughout the ITP program. The personal factors of each participant brought them to the VPU ITP program specifically. Personal factors include participants' demographics, prior learning experiences, prior teaching experiences, and support systems. They also dictated how individuals viewed and related to the contextual factors they encountered.

The next layer in the model is contextual factors. For this model, contextual factors are participants' experiences in the ITP program, their placement classroom, school, and district, as well as broader societal issues. I decided to separate contextual from personal factors due to the focus on the program and associated educational environment. The participants' personal factors influenced how they engaged with their contextual factors. For example, Azula's placement school was her former high school. This connection between personal and contextual factors greatly impacted her willingness to shift her thinking about social issues that appeared in the data she uncovered about her school's discipline rate. The contextual factors were the background for where and how participants engaged with the ITP program's ideologies and learning to challenge them.

Following the different factors are the ideologies presented in the ITP program. This layer in the original model was focused on ideologies and continues to be in the final version. However, one key change to this layer is the critical learning task of challenging ideology. It was no mistake when Brookfield chose challenging ideology as the first of seven learning tasks. He (2005) stated, "The first, and arguably the preeminent, learning task embedded in critical theory is that of challenging ideology" (p. 40). It quickly became apparent that before a teacher candidate decided to align or resist an ideology, they first challenged or critiqued it. In challenging ideology, evidence from all participants emerged where they critiqued the ideologies

of critical pedagogy and 3D science teaching and learning. Their critiques of the two ideologies led them to become more willing to align or resist their thinking and later practice within them. Importantly, their critiques occurred within the contextual factors (e.g., the ITP program) that were interpreted through their personal factors (e.g., Prior learning experience). All three layers worked together and were constantly reevaluated within teacher candidates' thinking and their experiences of the remaining critical adult learning tasks.

Like the ideological layer of the CLSR model, teacher candidate thinking did not move from its placement in the original model. Instead, the remaining six critical adult learning tasks moved inward to this layer. Teacher candidate thinking encompasses many areas, such as beliefs and knowledge about students, learning, and the role of the teacher. Many of the learning tasks focus on internal shifts in thinking. For instance, Azula and Madelia's experiences of questioning their thinking and observations were explored in contesting hegemony. Starr and Jacob confronted their assumptions about teaching science and their roles to reclaim reasoning. Engaging in the remaining critical adult learning tasks often started and focused on ways of teacher candidate thinking, which was impacted by their ability to challenge the ideologies put forth by the ITP program. Brookfield's writing about the critical adult learning tasks focused on how adult educators can structure learning experiences for their students to participate in the tasks. The actual descriptions of practice for contesting hegemony or reclaiming reasoning were limited. This study provides examples of what this looks like for adult learners as well as teacher candidates. Ultimately, participants' thinking and involvement in the critical adult learning tasks appeared within their practice.

At the heart of both versions of the model is practice. It is here that all the layers culminate and reveal themselves. I saw this in the participants' data. Participants' practice often

revealed their thinking and level of engagement in the critical learning tasks. An example of this was in unmasking power, where all participants' field placement observation scores were analyzed to see how they recognized power and used agency in their practice. The instructional practice science teacher candidates used reflected their thinking about themselves, science, their students, and learning. For instance, Starr shifted her practice throughout the ITP program to become more student-centered with small group work, open-ended questions, and explorative activities. Their decisions in their practice revealed how they chose to participate in the different critical learning tasks. Azula made the small change in how students took notes in the classroom from traditional guided notes to challenging students to decide what they needed to record. This seemingly small decision demonstrated Azula contesting hegemony and unmasking power in the classroom. The depth of usage of critical adult learning tasks in their practice exposed how participants were challenging critical pedagogy and/or 3D science teaching and learning ideologies. Their context, whether in their placement classroom or methods courses, influenced the level at which participants could engage in challenging ideologies. Lastly, their personal factors dictated whether they were willing to push the boundaries and themselves to utilize the ideologies in which their thinking was grounded during their teaching.

The critical adult learning tasks (Brookfield, 2005) and the teacher-centered systemic reform (TCSR) model (Woodbury & Gess-Newsome, 2002) do not address teacher candidates. The proposed model explicitly examines why science teacher candidates align with or resist critical science ideologies. Brookfield (2005) claims adult learners must experience every learning task in order to become socially and politically aware of the inequities and systemic exploitation of others. However, if that is the case, four out of my five participants are not socially or politically aware. This would mean Jacob, Madelia, Starr, and Tam are lacking. Based

on my analysis, I cannot agree with this statement, particularly Jacob, Madelia, and Starr. While it might be ideal for an adult to participate in all critical adult learning tasks, it may not be feasible due to a multitude of factors. Perhaps their context does not alienate them, or maybe due to their personal factors, like age, they are not ready to learn democracy as defined by Brookfield. Based on the results of this study, an adult may not have to experience all seven critical adult learning tasks to become socially and politically aware of the inequities and systemic exploitation of others. However, I would propose that the depth at which they are aware may grow and change throughout learning based on their personal and contextual factors.

Boundaries of Study

As mentioned in chapter three, several boundaries impacted the findings of this study. After conducting and analyzing the study, the implications and importance of these boundaries must be considered when discussing the findings.

1. COVID-19: The impact of COVID-19 on the ITP program during the time of this study cannot be understated. While participants were able to attend their placements in person, their university supervisor was not. Due to policies put in place by school districts, Mrs. Reid conducted their field performance observations through a virtual platform synchronously. This requirement most likely impacted what she could observe happening in the classroom. I was also not allowed to observe participants. Because of this, I had to rely on the perspectives of Mrs. Reid and the participants' mentor teachers to understand how they were implementing social justice and 3D science teaching and learning. This comes with its own challenges. The possibility that observers were not actively looking for teaching moves that supported social justice and/or 3D science teaching and learning is high. During data analysis, I interpreted observers' feedback as best I could, but my

own experiences as a university supervisor and science teacher influenced how I understood their thinking.

2. Sampling: Azula, Jacob, Madelia, Starr, and Tam are unique participants not often found in teacher preparation research. Their experiences and personal factors brought with them to the ITP program present a new, important, and often overlooked area of science education research. Azula and Tam's voices represent populations that are rare in science education research. While they do not speak for everyone similar to them, they offer insight into how Indian-American women and Vietnamese men can make sense of these new ideologies in their context. The communities Starr, Jacob, and Madelia are members of are beginning to appear within science education research. Their voices offer support and greater insight into this work.
3. My Positionality: As a White, middle-aged American female science educator, my experience and understanding of the world differed from all my participants. Some aspects of my identity and the participants' were in contrast, such as religion, gender, and race or ethnicity. This difference influenced how I interpreted and analyzed participants' data. An example of this comes from my data analysis of Tam's experience. I struggled with Tam. I struggled to make sense of his thinking about his students and his role in the classroom because it directly opposed mine. My positionality as an American hindered my understanding of Tam's expectations in the classroom. As I explored how Tam's culture informed his experience in the ITP program, I began to understand how I felt the impact of a cultural barrier between us. This experience allowed me to place my personal feelings towards Tam into a better context that pushed me to recognize and question my ideologies around the role of the teacher in the classroom.

Conclusions

Science teacher candidates need to become aware of their own identities, skills, intellect, criticality, and joy to deeply align with critical science ideologies.

In a review of literature focused on teacher candidate preparation, A. Lin Goodwin and Kelsey Darity (2019) found only four percent (76) of 1796 articles pertained to preparing teachers to implement social justice in their classrooms. Sixty-nine percent of the 76 articles focused on understanding the beliefs of teacher candidates about social justice. For many of these articles, teacher candidates experienced an intervention in their ITP program that caused them to become more aware of their biases, reduce deficit thinking, and have greater cultural understanding (Goodwin & Darity, 2019). Still, teacher candidates, specifically White teacher candidates, often resist critical pedagogy, social justice, and multicultural education (Han 2013, 2014; Hatch & Groenke 2009; Marx 2006). Han et al. (2015) found that while more diverse teacher candidates in an urban ITP program came to be more accepting of critical pedagogy, they still displayed only a surface willingness to accept social justice curriculum. In my study, four out of five participants deeply engaged with critical pedagogies in their practice throughout practicum. My findings demonstrated that when science teacher candidates are taught how to question the norms of society and are asked to reflect, they align more strongly with critical science ideologies. Throughout their ITP program, participants were asked to engage with critical texts, acknowledge their positionality, reflect on their own thinking and learning experiences, and interrogate their role within society. The level at which students engaged in these tasks encouraged them to become aware of their identities, skills, intellect, criticality, and joy they bring into the classroom. This awareness provided them the opportunity to shift not only their practice but also their ideologies toward teaching science to all of their students.

I recommend further research around induction teachers from the ITP program to examine the upkeep of critical science ideologies in their practice. Teachers who graduated from an ITP program in the last five years have received more courses to support diverse learners, such as multilingual learners and students with learning disabilities, than their peers. Yet, teachers still struggle to support diverse learners (National Center for Education Statistics, 2021). Even when science teachers are provided well-aligned NGSS curriculum, they may make decisions that revert instruction to being teacher-centered (McNeill et al., 2017). For these reasons, following graduates of the ITP program into the induction years would allow researchers to observe how their teachers continue to align with or begin to resist critical science ideologies. With this knowledge, teacher educators could design ITP programs to better support teacher candidates in maintaining critical science ideologies in their careers.

ITP programs should offer professional development to mentor teachers that align with the ideologies presented to science teacher candidates.

David Stroupe and James B. Hancock II (2022) worked with science mentor teachers to aid in their understanding of the Next Generation Science Standards (NGSS) and Ambitious Science Teaching (AST) practices. Following four mentor teachers through a yearlong professional development while mentoring, Stroupe and Hancock (2022) found how the mentor teacher views their role in the practicum process impacted their willingness to engage with NGSS and AST practices. Two mentor teachers treated their science teacher candidates as partners in the classroom, while the other two mentors viewed their role as guiding the science teacher candidates into "real teaching" (Stroupe & Hancock, 2022, p. 7). Consequently, one of these mentors quit the program altogether, and the other blamed NGSS and AST practices for his science teacher candidate's classroom facilitation issues. While my study only has the data from

the mentor teachers in the form of field performance observations, participants reported the role of the mentor to be impactful in their ability to critique critical science ideologies. This was because the mentor teachers of all participants reportedly did not purposefully ground their work in critical science ideologies. Yet, what if they did? Science teacher candidates would have more opportunities to observe modeling of critical science ideologies and become more confident in their ability due to informed feedback specific to elements of critical science ideologies. Further research is required to explore the impact on a science teacher candidate's willingness to align with or resist critical science ideologies when they work with a mentor teacher whose ideologies align with the ITP program.

Science education research should begin to examine critical pedagogy and 3D science teaching and learning as one idea and not separate.

A quick review of chapter two and a search online will reveal little, if any, research focused explicitly on science teacher candidates working to incorporate both critical pedagogy and 3D science teaching and learning into their practice. Many articles focus on the different elements of 3D science teaching and learning. As seen earlier in this section, close to 2,000 articles were related to preparing teachers to implement social justice in their classrooms. Yet, science education researchers have not combined the two ideologies when researching science teacher preparation. My study has demonstrated the importance and significance of exploring both newly presented ideologies within teacher preparation. We have seen how science teacher candidates work to combine and form their own ideologies independently from each other around critical science education. While research dedicated towards the progression of critical pedagogy and science education reform is valuable, a key component as to why science teacher candidates do not maintain these ideals in their practice may be the interplay between these two

ideologies for science teacher candidates. Because of this, I recommend conducting more research with an eye toward how critical pedagogy and 3D science teaching and learning work together to support science education reform in the K-12 classroom.

ITP programs that center the ideals of social justice and promote NGSS-based pedagogy are key locations for students who seek to become critical science teachers. If social justice is not at the heart of the ITP program, it is unrealistic for critical pedagogy to become the foundation for its' teacher candidates. If social justice is regulated to a single course and not woven throughout teacher candidates' ITP experience, they will not challenge their ideologies and participate in the critical adult learning tasks. This study demonstrated how first presenting broad societal issues and asking students to challenge their understanding of education leads them to search for answers. Many of them found their answer within NGSS-based pedagogies grounded in critical pedagogy. Their shift in thinking was reinforced throughout the ITP program by their peers, students, and university mentors. A key component was continual reflection, challenge to ideology, and actions that caused teacher candidates to participate in the critical adult learning tasks. Without this, science teacher candidates may begin to shift their thinking but revert to what feels comfortable and safe. Researching instructional strategies, particular readings, and experiences science teachers have in socially just-centered ITP programs will support a critical science ideology that incorporates critical pedagogy and 3D science teaching and learning.

Concluding Remarks

My head hurt. It hurt in the "what-the-Hell-Did-I-just-experience" type of way. I had just finished analyzing the data of all five participants. Earlier in the day, while sitting on my parents' back porch, I had remarked to my husband that I was ready to write about Azula, Jacob, Madelia, Starr, and Tam's experiences. Little did I know that I would also be writing about mine. We were

all adult learners participating in critical learning for systemic reform. This study demonstrated the choices adults make to learn and challenge themselves. At the heart, it represents the feelings, processes, and changes we seek as life-long learners who want to be the best version of ourselves. The findings suggest ITP programs must teach to the whole student and be a safe space that encourages them to push back on the status quo, question, and, above all, reflect on what they value.

REFERENCES

Allen, M. (2010). *Misconceptions in primary science*. Open University Press.

Althusser, L. (2010). Ideology and ideological state apparatuses (notes towards an investigation) (1970). *Cultural theory: An anthology*, 204-22.

Ajayi, L. (2017). Preservice teachers' perspectives on their preparation for social justice teaching. *The Educational Forum, 81*(1), 52-67.

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for science literacy*. Oxford University Press.

Ames, R. T. (2014). A review of science standard history culminating with Next Generation Science Standards. *Journal of Education and Training, 1*(2), 48-57.

Aminger, W., Hough, S., Roberts, S. A., Meier, V., Spina, A. D., Pajela, H., ... & Bianchini, J. A. (2021). Preservice Secondary Science Teachers' Implementation of an NGSS Practice: Using Mathematics and Computational Thinking. *Journal of Science Teacher Education, 32*(2), 188-209.

Anderson, C.S. (1982). The search for school climate: A review of the research. *Review of Educational Research, 52*(3), 368–420.

Arellano, A., Cintrón, J., Flores, B., & Berta-Ávila, M. (2016). Teaching for critical consciousness: Topics, themes, frameworks, and instructional activities. In A. Valenzuela (Ed.) *Growing critically conscious teachers: A social justice curriculum for educators of Latino/a youth* (pp. 39-66). Teachers College Press.

Bahcivan, E., & Cobern, W. W. (2016). Investigating coherence among Turkish elementary science teachers' teaching belief systems, pedagogical content knowledge and practice. *Australian Journal of Teacher Education, 41*(10), 63–86.

Bandura, A. (1986). *Social foundation of thought and action: A social cognitive theory*. Prentice-Hall.

Banilower, E. R. (2019). Understanding the big picture for science teacher education: The 2018 NSSME+. *Journal of Science Teacher Education, 30*(3), 201-208.

Banilower, E. R., Smith, P. S., Malzahn, K. A., Plumley, C. L., Gordon, E. M., & Hayes, M. L. (2018). *Report of the 2018 NSSME+*. Retrieved from Chapel Hill, NC

Barton, A. C., & Osborne, M. D. (2001). Chapter 1: Marginalized Discourses and Pedagogies: Constructively Confronting Science for All in Classroom Practice. *Counterpoints*, *150*, 7–32.

Baum, S., & O'Malley, M. (2003). College on credit: How borrowers perceive their education debt. *Journal of Student Financial Aid, 33*(3): 7–19.

Bell, T. H. (1993). Reflections one decade after "A Nation at Risk." *Phi Delta Kappan. 74*(8), 592-597

Bennett deMarrais, K., & LeCompte, M. D., (1999) *The way schools work: A sociological analysis of education*. Longman.

Bhatnagar, R., Kim, J., Many, J. E., Barker, K., Ball, M., & Tanguay, C. (2016). Are we making our social justice framework salient? Candidates' perceptions of urban teacher education program effectiveness. *National Teacher Education Journal, 9*(2), 27–39.

Bhatnagar, R., Tanguay, C. L., Sullivan, C., & Many, J. E. (2021). Observation of field practice rubric: Establishing content validity and reliability. *Georgia Educational Researcher, 18*(2), 1-23.

Bogdan, R. C., & Biklen, S. K. (2016). *Qualitative research for education: An introduction to theories and methods* (5th ed.). Pearson.

Borko, H., & Mayfield, V. (1995). The roles of the cooperating teacher and university supervisor in learning to teach. *Teaching and Teacher Education, 11*(5), 501-518.

Braaten, M. (2018). Persistence of the two-worlds pitfall: Learning to teach within and across settings. *Science Education, 103*(1), 61-91.

Brookfield, S. D. (2005). *The power of critical theory: Liberating adult learning and teaching*. Jossey-Bass.

Bryk, A., & Driscoll, M. E. (1988). *The high school as community: Contextual influences and consequences for students and teachers*. National Center on Effective Secondary Schools.

Bryk, A., Camburn, E., & Louis, K. S. (1999). Professional community in Chicago elementary schools: Facilitating factors and organizational consequences. *Educational Administration Quarterly, 35*, 751 – 781.

Buehl, M. M., & Beck, J. S. (2015). The relationship between teachers' beliefs and teachers' practices. In H. Fives & M. G. Gill (Eds.). *International handbook of research on teachers' beliefs* (pp. 66–84). Routledge.

Buldur, S. (2017). A longitudinal investigation of the preservice science teachers' beliefs about science teaching during a science teacher training programme. *International Journal of Science Education, 39*(1), 1-19.

Bullock, P. L., & Freedman, D. M., (2006). (Re)visions to a secondary teacher education course: Trials and triumphs in attempting to disrupt hegemonic understandings and performances of education. *Teaching and Teacher Education, 22*, 135-149.

Bybee, R. W. (2014). NGSS and the next generation of science teachers. *Journal of Science Teacher Education, 25*(2), 211-221.

Bybee, R. W. (2011). Science and engineering practices in K-12 classrooms: Understanding A

Framework for K-12 Science Education. *Science Teacher, 78*(9), 34-40.

Çağlar, Ç. (2013). The relationship between the levels of alienation of the education faculty students and their attitudes towards the teaching profession. *Kuram ve Uygulamada Egitim Bilimleri, 13*(3), 1507-1513.

Calabrese Barton, A., & Osborne, M. O. (2001). Marginalized discourses and pedagogies: Constructively confronting science for all in classroom practice. In *Counterpoints* (pp. 7-32). Peter Lang AG.

Calabrese Barton, A. (1998). Reframing "science for all" through the politics of poverty. *Educational Policy, 12*(5), 525-541.

Carter Andrews, D. J., Castro, E., Cho, C. L., Petchauer, E., Richmond, G., & Floden, R. (2019). Changing the narrative on diversifying the teaching workforce: A look at historical and contemporary factors that inform recruitment and retention of teachers of color. *Journal of Teacher Education, 70(*1), 6-12.

Carver-Thomas, D. (2018). *Diversifying the teaching profession: How to recruit and retain teachers of color*. Learning Policy Institute.

Carver-Thomas, D., & Darling-Hammond, L. (2019). The trouble with teacher turnover: How teacher attrition affects students and schools. *Education Policy Analysis Archives, 27*(36), 1-32.

Cattley, G. (2007). Emergence of professional identity for the pre-service teacher. *International Education Journal, 8*(2), 337-347.

Chen, R. F., Eisenkraft, A., Fortus, D., Krajcik, J., Neumann, K., Nordine, J., & Scheff, A. (Eds.). (2014). *Teaching and Learning of Energy in K – 12 Education*. Springer International Publishing.

Chesnutt, K., Gail Jones, M., Corin, E. N., Hite, R., Childers, G., Perez, M. P., ... & Ennes, M. (2019). Crosscutting concepts and achievement: Is a sense of size and scale related to achievement in science and mathematics?. *Journal of Research in Science Teaching, 56*(3), 302-321.

Cipollone, K., Zygmunt, E., Robert Scaife, P., & Scaife, M. W. (2022). "Let's create the table": Reengaging democracy in teacher preparation through radical reciprocity. *Teachers College Record, 124*(3), 61-88.

Clarke, A., Triggs, V., & Nielsen, W. (2014). Cooperating teacher participation in teacher education: A review of the literature. *Review of Educational Research, 84*(2), 163-202.

Clift, R. T., & Brady, P. (2005). Research on methods courses and field experiences. In M. Cochran-Smith, & K. Zeichner (Eds.), *Studying Teacher Education: The report of the AERA Panel on Research and Teacher Education* (pp. 309-424). Erlbaum.

Cohen, E., Hoz, R., & Kaplan, H. (2013). The practicum in preservice teacher education: A review of empirical studies. *Teaching Education, 24*(4), 345-380.

Colin, S., & Preciphs, T. (1991). Perceptual patterns and the learning environment: Confronting White racism. In R. Hiemstra (Ed.), *Creating environments for effective adult learning* (pp. 61-70). Jossey-Bass.

Cooper, M. M., Posey, L. A., & Underwood, S. M. (2017). Core ideas and topics: Building up or drilling down?. *Journal of Chemical Education, 94*(5), 541-548.

Cooper, M. M. (2020). The crosscutting concepts: Critical component or "third wheel" of three-dimensional learning?. *Journal of Chemical Education, 97*(4), 903-909.

Council, N. R. (2010). *Preparing teachers: Building evidence for sound policy*. doi:10.17226/12882

Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of research in science teaching, 44*(4), 613-642.

Crawford, B. A. (2014). From inquiry to scientific practices in the science classrooms. In N. Lederman & S. Abell (Eds.), *Handbook of research in science education*, vol. II (pp. 515–541). Taylor and Francis.

Creswell, J. W. (2007). *Qualitative inquiry & research design: Choosing among five approaches* (2nd ed.). Sage.

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). Sage.

Crooks, C. V., Jaffe, P. G., & Rodriguez, A. (2017). Increasing knowledge and self-efficacy through a pre service course on promoting positive school climate: The crucial role of reducing moral disengagement. *Advances in School Mental Health Promotion, 10*(1), 49-64.

Crotty, M. (2015). *The foundations of social research: Meaning and perspective in the research process.* Sage.

Cuban, L. (1993). *How teachers taught: Constancy and change in American classrooms 1890-1990* (2nd ed.). Teachers College Press.

Darling-Hammond, L. (2000). Teacher quality and student achievement: A review of state policy evidence. *Education Policy Analysis Archives, 8*(1)

Darling-Hammond, L. (1990). Teaching and knowledge: Policy issues posed by alternate certification for teachers. *Peabody Journal of Education, 67*(3), 123-154.

Darling-Hammond, L., & Sykes, G. (Eds.). (1999). *Teaching as the learning profession: Handbook of policy and practice*. Jossey Bass.

Deal, T. E., & Peterson, K. D. (1991). *The principal's role in shaping school culture* (Vol. 1). US Dept. of Education, Office of Educational Research and Improvement, Programs for the Improvement of Practice.

Deroo, M. R., & Ponzio, C. M. (2021). Fostering Pre-Service Teachers' Critical Multilingual Language Awareness: Use of Multimodal Compositions to Confront Hegemonic Language Ideologies, *Journal of Language, Identity & Education*.

Dincer, A., Goksu, A., Takkac, A., & Yazici, M. (2013). Common characteristics of an effective English language teacher. *International Journal of Educational Researchers, 4*(3), 1–8.

Driver, R., Squires, A., Rushworth, P., & Wood-Robnson, V. (1994). *Making sense of secondary science: Research into children's ideas*. Routledge.

Duckworth, V., & Maxwell, B. (2015). Extending the mentor role in initial teacher education: Embracing social justice. *International Journal of Mentoring and Coaching in Education, 4*(1), 4-20.

Duenkel, N., Pratt, J., & Sullivan, J. (2014). Seeking wholeheartedness in education: Power, hegemony, and transformation. *Journal of Transformative Education, 12*(3), 266-291.

Duffin, D. L., Ziebarth-Bovill, J., & Krueger, R. H. (2019). Building Democratic Capacity in Preservice Teachers. *Delta Kappa Gamma Bulletin, 86*(1).

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. *Review of Research in Education*, *32*(1), 268–291.

Duschl, R. A. (2012). The second dimension – crosscutting concepts. *Science Teacher, 79*(2), 34-38.

Ely, M., Anzul, M., Friedman, T., Garner, D., & McCormack Steinmetz, A. (1991). Reflecting. *Doing qualitative research: Circles within circles*, 179-226.

Enderle, P. (2020a). *Introduction to Secondary Teaching* [Syllabus]. Atlanta, GA: Middle and Secondary Education, Georgia State University.

Enderle, P. (2020b). *Principles of Science Instruction* [Syllabus]. Atlanta, GA: Middle and Secondary Education, Georgia State University.

Enderle, P. (2021). *Theory & Pedagogy of Science Instruction*[Syllabus]. Atlanta, GA: Middle and Secondary Education, Georgia State University.

Enderle, P., Dentzau, M., Roseler, K., Southerland, S. S., Granger, E., Hughes, R., . . . Saka, Y. (2014). Examining the influence of RETs on science teacher beliefs and practice. *Science Education, 98*(6), 1077-1108.

Ewing, E. L. (2018). *Ghosts in the Schoolyard*. University of Chicago Press.

Ezzy, D. (2002). *Qualitative analysis: Practice and innovation*. Allen & Unwin.

Fay, J., & Fay, C. (2016). *Teaching with love and logic: Taking control of the classroom*. Love and Logic Press, Inc.

Feiman-Nemser, S., & Buchmann, M. (1985). Pitfalls of experience in teacher preparation. *Teachers College Record, 87*(1), 53-65.

Fernández-Armesto, F. (2014). *Our America: A Hispanic History of the United States*. WW Norton & Company.

Fick, S. J. (2018). What does three-dimensional teaching and learning look like?: Examining the potential for crosscutting concepts to support the development of science knowledge. *Science Education, 102*(1), 5-35.

Fives, H., & Buehl, M. M. (2016). Teachers' beliefs, in the context of policy reform. *Policy Insights from the Behavioral and Brain Sciences, 3*(1), 114–121.

Fleming, C.M. (2018). *How to be Less Stupid About Race.* Beacon Press.

Forbes, C. T. (2011). Preservice elementary teachers' adaptation of science curriculum materials for inquiry-based elementary science. *Science Education*, *95*(5), 927–955.

Foucault, M. (1977). *Discipline and punishment: The birth of the prison*. Vintage Books.

Foucault, M. (1982). The subject and power. In H. L. Dreyfus & P. Rabinow (Eds.), *Michel Foucault: Beyond structuralism and hermeneutics*. University of Chicago Press.

Freiberg, J., & Stein, T.A. (1999). Measuring, improving, and sustaining healthy learning environments. In J. Freiberg (Ed.), *School climate* (pp. 11–29). Falmer.

French, D. A., & Burrows, A. C. (2018). Evidence of science and engineering practices in preservice secondary science teachers' instructional planning. *Journal of Science Education and Technology, 27*(6), 536-549.

Fullan, M. G., with Stiegelbauer, S. (1991). *The new meaning of educational change*. Teachers College Press.

Fulmer, G. W., Tanas, J., & Weiss, K. A. (2018). The challenges of alignment for the Next Generation Science Standards. *Journal of Research in Science Teaching, 55*(7), 1076-1100.

García, O. (2009). *Bilingual education in the 21st century: A global perspective*. Wiley-Blackwell.

Gardiner, W. (2011) Mentoring in an urban teacher residency: Mentors' perceptions of year-long placements. *New Educator, 7*, 153-171.

Gay, G. (2018). *Culturally responsive teaching: Theory, research, and practice*. Teachers College Press.

Geertz, C. (1973). *The interpretation of cultures: Selected essays*. Basic Books, Inc., Publishers.

Gegenfurtner A., Lewalter D., Lehtinen E., Schmidt M., & Gruber H. (2020). Teacher expertise

and professional vision: Examining knowledge-based reasoning of pre-service teachers, in-service teachers, and school principals. *Frontiers in Education, (5)*59, 1-8.

Georgia Department of Education. (2019). Georgia parent survey. Retrieved from https://www.gadoe.org/wholechild/GSHS-II/Documents/GA%20Parent%20Survey.pdf

Georgia Department of Education. (2019). Georgia student survey: Grades 6-12. Retrieved from https://www.gadoe.org/wholechild/GSHS-II/Documents/GSHS_6-12.pdf

Georgia Department of Education. (2021). School climate star rating. https://www.gadoe.org/wholechild/Pages/School-Climate-Star-Rating.aspx

Georgia State University. (2021). *Course catalog: Science education, M.A.T.* https://catalogs.gsu.edu/preview_program.php?catoid=5&poid=1573&returnto=691

Gess-Newsome, J., Southerland, S. A., Johnston, A., & Woodbury, S. (2003). Educational reform, personal practical theories, and dissatisfaction: The anatomy of change in college science teaching. *American Educational Research Journal, 40*(3), 731-767.

Goodin, T. L., Caukin, N. G., & Dillard, H. K. (2019). Developing clinical reasoning skills in teacher candidates using a problem-based learning approach. *Interdisciplinary Journal of Problem-Based Learning, 13*(1).

Goodwin, A. L., & Darity, K. (2019). Social justice teacher educators: what kind of knowing is needed?. *Journal of Education for Teaching, 45*(1), 63-81.

Goodwin, D. (1994). Professional vision. *American Anthropology, 96*, 606–633.

Gore, J. M. (1993). *The struggle for pedagogies: Critical and feminist discourses as regimes of truth*. Routledge.

Gotwals, A. W., & Birmingham, D. (2016). Eliciting, identifying, interpreting, and responding to students' ideas: Teacher candidates' growth in formative assessment practices. *Research*

in Science Education, 46(3), 365-388.

Gramsci, A., & Buttigieg, J. (2002). From the 'Prison Notebooks'. *Daedalus, 131*(3), 71-83.

Grossman, P., & Loeb, S. (Eds). (2008). *Alternative routes to teaching: Mapping the new landscape of teacher education*. Harvard Education Press.

Guyton, E., Fox, M. C., & Sisk, K. A. (1991). Comparison of teaching attitudes, teacher efficacy, and teacher performance of first year teachers prepared by alternative and traditional teacher education programs. *Action in Teacher Education, 13*(2), 1-9.

Hammerness, K., Stroupe, D., & Matsko, K. K. (2023). Learning to teach equitably: Theoretical frameworks and principles for international research and practice. In *The Palgrave Handbook of Teacher Education Research* (pp. 1259-1292). Cham: Springer International Publishing.

Han, K. T. (2013). ‘‘These things do not ring true to me’’: Preservice teacher dispositions to social justice literature in a remote state teacher education program. *The Urban Review, 45*(2), 143–166.

Han, K. T. (2014). Moving racial discussion forward: A counterstory of racialized dynamics between an Asian-woman faculty of color and White preservice teachers in traditional rural America. *The Journal of Diversity in Higher Education, 7*(2), 126–146.

Han, K. T., Madhuri, M., & Scull, W. R. (2015). Two sides of the same coin: Preservice teachers’ dispositions towards critical pedagogy and social justice concerns in rural and urban teacher education contexts. *The Urban Review, 47*(4), 626-656.

Hancock, D. R., & Algozzine, B. (2017). *Doing case study research: A practical guide for beginning researchers* (3rd ed.). Teachers College Press.

Hancock, E. S., & Gallard, A. J. (2004). Preservice science teachers' beliefs about teaching and

learning: The influence of K-12 field experiences. *Journal of Science Teacher Education, 15*(4), 281-291.

Hargreaves, A. (1994). *Changing teachers, changing times: Teachers' work and culture in the postmodern age*. Teachers College Press.

Harré, R., & Van Langenhove, L. (1999). Positioning theory. *The discursive turn in social psychology*, 129-136.

Hatch, J. A., & Groenke, S. L. (2009). Issues in critical teacher education: Insights from the field. In S. L. Groenke & J. A. Hatch (Eds.), *Critical pedagogy and teacher education in the neoliberal era: Small openings* (pp. 63–84). Springer.

Heck, R.H., & Marcoulides, G.A. (1996). School culture and performance: Testing the invariance of an organizational model. *School Effectiveness and School Improvement,* 7, 76–95.

Hoeg, D. G., & Bencze, J. L. (2017). Values underpinning STEM education in the USA: An analysis of the Next Generation Science Standards. *Science Education, 101*(2), 278-301.

hooks, b. (2014). *Teaching to transgress*. Routledge.

Horkheimer, M. (1974). Eclipse of Reason. 1947. New York: *Continuum*.

Horkheimer, M., & Adorno, T. W. (1972). *Dialectic of Enlightenment: Max Horkheimer and Theodor W. Adorono*. Seabury Press.

Hoy, W.K., Tarter, C.J., & Kottkamp, R.B. (1991). *Open schools/healthy schools: Measuring organizational climate*. Corwin Press

Ives, P. (2004). *Language and hegemony in Gramsci*. Pluto Press.

Izadinia, M. (2013). A review of research on student teachers' professional identity. British Educational Research Journal, 39(4), 694-713.

Izadinia, M. (2015). Student teachers' and mentor teachers' perceptions and expectations of a mentoring relationship: do they match or clash? *Professional Development in Education, 42*(3), 387-402.

Jackson, T. O. (2015). Perspectives and insights of preservice teachers of color on developing culturally responsive pedagogy at predominantly white institutions. *Action in Teacher Education, 37*(3), 223–237.

Jackson, T. O., & Kohli, R. (2016). Guest editors' introduction: The state of teachers of color. *Equity & Excellence in Education, 49*(1), 1-8.

Jelmberg, J. (1996). College-based teacher education versus state-sponsored alternative programs. *Journal of Teacher Education, 47*(1), 60-66.

Johnson, S. M. (1990). *Teachers at work: Achieving success in our schools*. Basic Books.

Kagan, D. M. (1992). Professional growth among preservice and beginning teachers. *Review of Educational Research, 62*(2), 129–169.

Kahn-Cullors, P. (2018). *When They Call You a Terrorist*. St. Martin's Press.

Kang, N.-H. (2008). Learning to teach science: Personal epistemologies, teaching goals and practices of teaching. *Teaching and Teacher Education, 24*, 478 – 498.

Katsh-Singer, R., McNeill, K. L., & Loper, S. (2016). Scientific argumentation for all? Comparing teacher beliefs about argumentation in high, mid, and low socioeconomic status schools. *Science Education, 100*(3), 410-436.

Kelchtermans, G. (1993). Getting the story, understanding the lives: from career stories to teachers' professional development. *Teaching and Teacher Education, 9*(5), 443-456.

Kind, V. (2016). Preservice science teachers' science teaching orientations and beliefs about science. *Science Education, 100*(1), 122-152.

Koballa, T. R., Glynn, S. M., Upson, L., & Coleman, D. C. (2005). Conceptions of teaching science held by novice teachers in an alternative certification program. *Journal of Science Teacher Education, 16*, 287-308.

Krajcik, J. S., Rivet, A. E., & Duncan, R. G. (2016). *Disciplinary Core Ideas: Reshaping Teaching and Learning*. NSTA Press.

Kreisberg, S. (1992). *Transforming power: Domination, empowerment, and education*. State University of New York Press.

Ladson-Billings, G. (2006). From the achievement gap to the education debt: Understanding achievement in US schools. *Educational researcher*, *35*(7), 3-12.

Lederman, N. G. (2007). Nature of science: past, present, and future. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education* (pp. 831–880). Lawrence Erlbaum.

Lederman, N. G., & Abd-El-Khalick, F. (1998). Avoiding de-natured science: activities that promote understandings of the nature of science. In W. McComas (Ed.), *The nature of science in science education: rationales and strategies* (pp. 83–126). Kluwer Academic.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497–521.

Lederman, N. G., Lederman, J. S., & Abd-El-Khalick, F. (2006a). Building science partnerships and collaboration. In J. Rhoton & P. Shane (Eds.), Teaching science in the 21st century (pp. 257-272). United States of America: National Science Teachers Association.

Lederman, N. G., Lederman, J. S., & Abd-El-Khalick, F. (2006b). Building science partnerships and collaboration. In J. Rhoton & P. Shane (Eds.), *Teaching science in the 21st century* (pp. 257-272). United States of America: National Science Teachers Association.

Lederman, N. G., & Lederman, J. S. (2014). Research on teaching and learning of nature of science. In Lederman N. G., & Abel S. K. (Eds.) *Handbook of research in science education*, vol II. Routledge, Taylor and Francis.

Lee, O., Miller, E. C., & Januszyk, R. (2014). Next Generation Science Standards: All standards, all students. *Journal of Science Teacher Education, 25*(2), 223-233.

Lee, O. (1999). Equity implications based on the conceptions of science achievement in major reform documents. *Review of Educational Research, 69*(1), 83-115.

Lee, V. E., Bryk, A. S., & Smith, J. B. (1993). The organization of effective secondary schools. In L. Darling-Hammond (Ed.), *Review of Research in Education* (pp. 171-267). American Education Research Association.

Lehrer, R., & Schauble, L. (2006). Cultivating Model-Based Reasoning in Science Education. In R. K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences*. New York City: University Press.

Leithwood, K. A. (1992). *The principal's role in teacher development.* In M. Fullan & A. Hargreaves (Eds.), Teacher development and educational change. The Falmer Press.

Lewis, A.E., (2003). Race in the Schoolyard: Negotiating the Color Line in Classrooms and Communities. Rutgers University Press.

Lilach, M. (2020). [Not] speaking truth to power: Ethical dilemmas of teacher candidates during practicum. *Teaching and Teacher Education, 89*, 1-9.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Sage.

Lindgren, R., Morphew, J. W., Kang, J., Planey, J., & Mestre, J. P. (2021). Learning and transfer effects of embodied simulations targeting crosscutting concepts in science. *Journal of Educational Psychology*.

Lindsey, B. A., Heron, P. R. L., & Shaffer, P. S. (2012). Student understanding of energy: Difficulties related to systems. *American Journal of Physics*, *80*(2), 154–163.

Lofland, J., & Lofland, L. H. (2016). *Analyzing social settings: A guide to qualitative observation and analysis* (4th ed). Wadsworth/Thomson Learning.

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

Loughran, L. (2014). Developing understandings of practice: Science teacher learning. In N. G. Lederman & S. K. Abell (Eds.) *Handbook of research on science education volume II* (pp. 811-829). Routledge.

Loughran, J. (2019). Pedagogical reasoning: The foundation of the professional knowledge of teaching. *Teachers and Teaching, 25*(5), 523-535.

Love, B. L. (2019). *We want to do more than survive: Abolitionist teaching and the pursuit of educational freedom*. Beacon Press.

Lowell, B. R., Cherbow, K., & McNeill, K. L. (2021). Redesign or relabel? How a commercial curriculum and its implementation oversimplify key features of the NGSS. *Science Education, 105*(1), 5-32.

Luft, J. A., & Roehrig, G. H. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Journal of Science Education, 11*(2), 38-63.

Males, L. M., Sears, R., & Lawler, B. R. (2020). Equity and justice in the preparation of secondary mathematics teachers. In W. G. Martin, B. R. Lawler, A. E. Lischka, & W. M. Smith (Eds.). *The mathematics teacher education partnership: The power of a networked improvement community to transform mathematics teacher preparation volume IIII* (pp. 57-90). Information Age Publishing.

Marco-Bujosa, L. M., McNeill, K. L., & Friedman, A. A. (2019). Becoming an urban science

teacher: How beginning teachers negotiate contradictory school contexts. *Journal of Research in Science Teaching*, 1-30.

Marcuse, H. (1964). *One Dimensional Man*. Beacon Press.

Marcuse, H. (1969). *An essay on liberation*. Beacon Press.

Marcuse, H. (1972). *Counterrevolution and revolt*. Beacon Press.

Marcuse, H. (1978). Marcuse and the Frankfurt School: Dialogue with Marcuse. In B. Magee (ed.), *Men of Ideas*. Viking.

Marom, L. (2019). From experienced teachers to newcomers to the profession: The capital conversion of internationally educated teachers in Canada. *Journal of Teaching and Teacher Education*, *78*(2), 85-96.

Marx, K., & Engels, F. (1970). *The German ideology* (C.J. Arthur, Ed.). Lawrence & Wishart. (Original work published 1932)

Marx, K. (1992) [1844]. "Economic and Philosophical Manuscripts". *Early Writings*. Translated by Livingstone, Rodney; Benton, Gregory. London: Penguin Classics. pp. 279–400.

Marx, S. (2006). *Revealing the invisible: Confronting passive racism in teacher education*. Routledge.

Maslowski, R. (2006). A review of inventories diagnosing school culture. *Journal of Educational Administration, 44*(1), 6–35.

Matsko, K. K., Ronfeldt, M., Nolan, H. G., Klugman, J., Reininger, M., & Brockman, S. (2018). Cooperating teacher as model and coach: What leads to student teachers' perceptions of preparedness? *Journal of Teacher Education*, *71*(1), 1–22.

McNeill, K., Lizotte, D., Krajcik, J., & Marx, R. (2006). Supporting Students' Construction of Scientific Explanations by Fading Scaffolds in Instructional Materials. *Journal of the*

Learning Sciences, *15*(2), 153–191.

McNeill, K. L., Pimentel, D. S., & Strauss, E. G. (2013). The impact of high school science teachers' beliefs, curricular enactments and experience on student learning during an inquiry-based urban ecology curriculum. *International Journal of Science Education, 35*(15), 2608-2644.

McNeill, K. L., González-Howard, M., Katsh-Singer, R., & Loper, S. (2017). Moving beyond pseudoargumentation: Teachers' enactments of an educative science curriculum focused on argumentation. *Science Education, 101*(3), 426–457.

McDonald, C. V. (2017). Who is teaching science in our high schools? Exploring factors influencing pre-service secondary science teachers' decisions to pursue teaching as a career. *Teaching Science, 63*(4), 33-44.

Mensah, F. M. (2008a). Agency, identity, and social justice education: Preservice teachers' thoughts on becoming agents of change in urban elementary science classrooms. *Research in Science Education, 38*(5), 589-610.

Mensah, F.M. (2008b). Preparing preservice teachers for urban elementary science classrooms: Challenging cultural biases toward diverse students. *Journal of Science Teacher Education, 19*(1), 85–109.

Mensah, F. M. (2009). Confronting assumptions, biases, and stereotypes in preservice teachers' conceptualizations of science teaching though the use of book club. *Journal of Research in Science Teaching, 46*(9), 1041-1066.

Mensah, F. M. (2013) Theoretically and practically speaking, what is needed in diversity and equity in science teaching and learning? *Theory into Practice*, *52*(1), 66–72.

Mensah, F. M. (2019). Finding Voice and Passion: Critical Race Theory Methodology in Science

Teacher Education. *American Educational Research Journal, 56*(4), 1412–1456.

Merriam, S. B. (2001). *Qualitative research and case study applications in education* (Rev. ed.). Jossey-Bass.

Miller, E., Manz, E., Russ, R., Stroupe, D., & Berland, L. (2018). Addressing the epistemic elephant in the room: Epistemic agency and the next generation science standards. *Journal of Research in Science Teaching, 55*(7), 1053-1075.

Mills, C. (2013). A Bourdieuian analysis of teachers' changing dispositions towards social justice: the limitations of practicum placements in pre-service teacher education. *Asia-Pacific Journal of Teacher Education, 41*(1), 41-54.

Muhammad, G. (2020). *Cultivating genius: An equity framework for culturally and historically responsive literacy*. Scholastic Incorporated.

National Center for Education Statistics. (2021). *Teacher training to meet diverse student needs before entering the classroom: Teacher preparation in 2017-2018*. Institute of Education Sciences.

National Commission on Teaching & America's Future. (1996, September). *What matters most: Teaching for America's future*. Teachers College, Columbia University.

National Commission on Teaching & America's Future. (1997, November). *Doing what matters most: Investing in quality teaching*. National Commission on Teaching and America's Future.

National Research Council (NRC). (1996). *National science education standards.* The National Academy Press.

National Research Council (NRC). (2012). *A framework for k-12 science education: Practices, crosscutting concepts, and core ideas.* The National Academy Press.

National Science Teaching Association. (2021). About the next generation science standards. Retrieved from https://ngss.nsta.org/about.aspx

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. The National Academy Press.

NGSS Lead States. (2013a). Appendix D "All standards, all students": Making the Next Generation Science Standards accessible to all students. In *Next Generation Science Standards: For states, by states, volume 2: Appendixes*, ed. NGSS Lead States, 25–39. National Academies Press.

NGSS Lead States. (2013b). Appendix E "Progressions within the next generation science standards": Making the Next Generation Science Standards accessible to all students. In *Next Generation Science Standards: For states, by states, volume 2: Appendixes*, ed. NGSS Lead States, 40–47. National Academies Press.

NGSS Lead States. (2013c). Appendix F "Science and engineering practices in NGSS": Making the Next Generation Science Standards accessible to all students. In *Next Generation Science Standards: For states, by states, volume 2: Appendixes*, ed. NGSS Lead States, 48–66. National Academies Press.

NGSS Lead States. (2013d). Appendix G "Crosscutting concepts": Making the Next Generation Science Standards accessible to all students. In *Next Generation Science Standards: For states, by states, volume 2: Appendixes*, ed. NGSS Lead States, 79–89. National Academies Press.

Nguyen, H. T. (2008). "Conceptions of Teaching by Five Vietnamese American Preservice Teachers." *Journal of Language, Identity & Education, 7* (2), 113–136.

Nieto, S. (2000). Placing equity front and center: Some thoughts on transforming teacher

education in the new century. *Journal of Teacher Education, 51*(3), 108–187.

Norville, K., & Park, S. (2021). The impact of cooperating teacher on master of arts in teaching preservice science teachers' pedagogical content knowledge. *Journal of Science Teacher Education, 32*(4), 444-468.

Nuñez, I., & Espinoza, K. (2019). Bilingual pre-service teachers' initial experiences: Language ideologies in practice, *Journal of Latinos and Education, 18(*3), 228-242.

Office of Institutional Effectiveness. (2021). *Graduate Programs: Enrollment* [Data set]. Georgia State University. https://dssapex.gsu.edu/pls/apex/f?p=113:22:13598881753831::NO:::

Office of Institutional Effectiveness. (2021). *Academic program review: Middle and Secondary Education* [Data set]. Georgia State University. https://dssapex.gsu.edu/pls/apex/f?p=113:33:::NO:::

Office of Institutional Effectiveness. (2020). *Georgia State University fact book: 2019-2020* [Data set]. Georgia State University. https://oie.gsu.edu/document/2019-2020-fact-book/?wpdmdl=3533

Olson, J. K., Tippett, C. D., Milford, T. M., Ohana, C., & Clough, M. P. (2015). Science teacher preparation in a North American context. *Journal of Science Teacher Education, 26*, 7-28.

Ore, T. E., & Kurtz, P. (2000). *The social construction of difference and inequality*. Mayfield Publishing.

Osbourne, J., Rafanelli, S., & Kind, P. (2018). Toward a more coherent model for science education than the crosscutting concepts of the Next Generation Science Standards: The affordances of styles of reasoning. *Journal of Research in Science Teaching, 55*(7), 962-

981.

Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*(3), 307–332.

Patrick, R. (2013). "Don't rock the boat": Conflicting mentor and pre-service teacher narratives of professional experience. *The Australian educational researcher*, *40*(2), 207-226.

Payne, K. A. (2018). Democratic teachers mentoring novice teachers: Enacting democratic practices and pedagogy in teacher education. *Action in Teacher Education, 40*(2), 133-150.

Peterson, K.D. (2002). Positive or negative. *Journal of Staff Development, 23*(3), 10-15

Peterson, R., & Treagust, D. (1995). Developing preservice teachers' pedagogical reasoning ability. *Research in Science Education, 25*, 291–305.

Philip, T. M., & Azevedo, F. S. (2017). Everyday science learning and equity: Mapping the contested terrain. *Science Education, 101*(4), 526–532.

Plachowski, T. J. (2019). Reflections of preservice teachers of color: Implications for the teacher demographic diversity gap. *Education Sciences, 144*(9), 1-19.

Pohan, C. A. (1996). Preservice teachers' beliefs about diversity: Uncovering factors leading to multicultural responsiveness. *Equity and Excellence in Education, 29*(3), 62–69.

Pohan, C. A., & Mathison, C. (1999). Dismantling defensiveness and resistance to diversity and social justice issues in teacher preparation. *Action in Teacher Education, 20*(1), 15–22.

Porlán, R., & Martín del Pozo, R. (2004). The conceptions of in-service and prospective primary school teachers about the teaching and learning of science. *Journal of Science Teacher Education, 15*(1), 39–62.

Powell, L. C. (1997). The achievement (k)not: Whiteness and ‘‘black underachievement’’. In M.

Fine, L. Weis, L. C. Powell, & L. Mun Wong (Eds.), *Off white: Readings on race, power, and society* (pp. 3–12). Routledge

Pruitt, S. L. (2014). The Next Generation Science Standards: The features and challenges. *Journal of Science Teacher Education, 25*(2), 145-156.

Richardson, V. (1996). The role of attitudes and beliefs in learning to teach. In J. Sikula (Ed.), *Handbook of research on teacher education* (pp. 102-119). Macmillan.

Ricks, P. H., & Yenika-Agbaw, V. (2021). Playing tug of war: The tensions of teacher candidates and their instructor during interactive picture book read-alouds. *Teaching and Teacher Education, 108*, 1-11.

Ricketts, A. (2014). Preservice elementary teachers' ideas about scientific practices. *Science & Education*, *23*(10), 2119–2135.

Riess, W., & Mischo, C. (2010). Promoting systems thinking through biology lessons. *International Journal of Science Education*, *32*(6), 705-725.

Rivera, S., & Titu, P. (2021). "I still don't see the problem with treating each student as an individual": Science preservice teachers' views on diversity and race in the science classroom. *Curriculum and Teaching Dialogue, 23*(2), 161-179.

Rodriguez, A. J. (1997). The dangerous discourse of invisibility: A critique of the National Research Council's National Science Education Standards. *Journal of Research in Science Teaching, 34*, 19-37.

Rodriguez, A.J. (1998). Strategies for counterresistance: Toward sociotransformative constructivism and learning to teach science for diversity and for understanding. *Journal of Research in Science Teaching, 35*, 589–622.

Rodriguez, A. J. (2015). What about a dimension of engagement, equity, and diversity practices?

A critique of the Next Generation Science Standards. *Journal of Research in Science Teaching, 52*(7), 1031-1051.

Ronfeldt, M., Brockman, S. L., & Campbell, S. L. (2018). Does cooperating teachers' instructional effectiveness improve preservice teachers' future performance? *Educational Researcher*, *47*(7), 405–418.

Russel, T., & Martin, A. K. (2014). Learning to teach science. In N. G. Lederman & S. K. Abell (Eds.) *Handbook of research on science education volume II* (pp. 871-888). Routledge.

Russell, T., & Martin, A. K. (2023). Learning to teach science. In *Handbook of research on science education* (pp. 1162-1196). Routledge.

Rutherford, F. J., & Ahlgren, A. (1989). *Science for all Americans*. Oxford University Press.

Sadler, T. D. (2006). "I won't last three weeks": Preservice science teachers reflect on their student-teaching experiences. *Journal of Science Teacher Education, 17*(3), 217-241

Sammons, P., Hillman, J., & Mortimore, P. (1995). *Key characteristics of effective schools: A review of school effectiveness research*. OFSTED.

Schoen, L. T., & Teddlie, C. (2008). A new model of school culture: A response to a call for conceptual clarity. *School effectiveness and school improvement, 19*(2), 129-153.

Scholarship Resource Center. (2021). Search for scholarships: Scholarship library [Data set]. Georgia State University. https://app.gsu.edu/scholarships/search_scholarships.cfm

Secada, W. G. (1994). Equity and the teaching of mathematics. In M. M. Atwater, K. Radzik-Marsh, & M. Strutchens (Eds.), *Multicultural education: Inclusion of all* (pp. 19-38). University of Georgia Press.

Seidel, T., & Stürmer, K. (2014). Modeling and measuring the structure of professional vision in preservice teachers. *American Education Research Journal, 51*, 739–771.

Settlage, J., Southerland, S. A., Smetan, L., & Lottero-Perdue, P. (2018). *Teaching science to every child: Using culture as a starting point* (3rd ed.). Routledge.

Seung, E., Park, S., & Narayan, R. (2011). Exploring elementary pre-service teachers' beliefs about science teaching and learning as revealed in their metaphor writing. *Journal of Science Education and Technology, 20*(6), 703-714.

Shulman, L. S. (1987). Knowledge and teaching: Foundation of the new reform. *Harvard Educational Review, 57*, 1-22.

Shuls, J. V., & Trivitt, J. R. (2015). Teacher Effectiveness: An analysis of licensure screens. *Education Policy, 29*(4), 645-675.

Shore, S. (1997). The White in the I: Constructions of difference and adult education. In *Proceedings of the 27th Annual SCUTREA Conference* (pp. 414-418). University of London.

Shore, S. (2000). "White practices" in adult education settings: An exploration. In *Proceedings of the 41st Annual Adult Education Research Conference* (pp. 423-427). University of British Columbia.

Silva Pimentel, D., & McNeill, K. L. (2013). Conducting talk in secondary science classrooms: Investigating instructional moves and teachers' beliefs. *Science Education, 97*(3), 367-394.

Simmons, P. E., Emory, A., Carter, T., Coker, T., Finnegan, B., Crockett, D.,…Labuda, K. (1999). Beginning teachers: Beliefs and classroom actions. *Journal of Research in Science Teaching, 36*, 930–954.

Siskin, L. S. (1994). *Realms of knowledge: Academic departments in secondary schools*. Falmer Press.

Smith, L. K. (2005). The impact of early life history on teachers' beliefs: in-school and out-of-school experiences as learners and knowers of science. *Teachers and Teaching: Theory and Practice, 11*, 5-36.

Smith, L. K., & Gess-Newsome, J. (2004). Elementary science methods courses and the National Science Education Standards: Are we adequately preparing teachers?. *Journal of Science Teacher Education, 15*(2), 91-110.

Songer, N. B. (2006). BioKIDS: An animated conversation on the development of curricular activity structures for inquiry science. In R. K. Sawyer (Ed.), *The Cambridge Handbook of The Learning Sciences* (pp. 355–371).

Strachan, S. L. (2020). An examination of two African American males' decisions to become secondary science teachers. *The High School Journal, 103*(4), 221-240.

Stake, R. (1995). *The art of case study research*. Sage.

Stoller, A. (2014). *Knowing and learning as creative action: A reexamination of the epistemological foundations of education*. Palgrave McMillian.

Storey, J. (2018). *Cultural theory and popular culture: An introduction* (8th ed.). Routledge.

Stroupe, D., & Hancock II, J. B. (2022). Examining mentor teachers' critical pedagogical discourses and participation in an era of changing science standards and pedagogies. *Teaching and Teacher Education, 109*, 1-11.

Szostkowski, A., & Upadhyay, B. (2019). Looking forward by looking back: Equity in science education as socially just and morally healing action. *Cultural Studies of Science Education, 14*(2), 335–353.

Talbert, J. E., & Perry, R. (1994, April 4-8). *How department communities mediate mathematics and science education reforms*. Paper presented at the American Educational Research

Association annual meeting, New Orleans, LA.

Talbert, J. E., & McLaughlin, M. W. (1996). Teacher professionalism in local school contexts. In I.F. Goodson & A. Hargreaves (Eds.), *Teachers' professional lives* (pp. 127-153). Falmer.

Thomas, J. A., Pedersen, J. E., & Finson, K. D. (2001). Validating the draw- a-science-teacher-test checklist (DASTT-C): Exploring mental models and teacher beliefs. *Journal of Science Teacher Education, 12*(3), 295–310.

Thompson, M., & Schademan, A. (2019). Gaining fluency: Five practices that mediate effective co-teaching between pre-service and mentor teachers. *Teaching and Teacher Education, 86*, 1-9.

Tobin, K., & McRobbie, C. J. (1997). Beliefs about the nature of science and the enacted science curriculum. *Science & Education, 6*, 355–371.

Tsai, C. (2002). Nested epistemologies: Science teachers' beliefs of teaching, learning and science. *International Journal of Science Education, 24*(8), 771–783.

Turkan, S., & de Jong, E. J. (2018). An exploration of preservice teachers' reasoning about teaching mathematics to English language learners. *Teacher Education Quarterly, 45*(2), 37–60.

U.S. Department of Education, Office of Postsecondary Education. (2006). *The secretary's fifth annual report on teacher quality: A highly qualified teacher in every classroom.* Author.

U.S. Department of Education, Higher Education Act Title II State Report Card System. (2015). *Enrollment, by state, by gender and race/ethnicity*. Retrieved from https://title2.ed.gov/Public/DataTools/Tables.aspx

U.S. Department of Education, Office of Planning, Evaluation and Policy Development. (2016).

The state of racial diversity in the educator workforce. Policy and Program Studies Service.

U.S. Department of Education. (2017). *A quarter century of changes in the elementary and secondary teaching force: From 1987 to 2012*. National Center for Education Statistics.

Vachliotis, T., Salta, K., & Tzougraki, C. (2014). Meaningful Understanding and Systems Thinking in Organic Chemistry: Validating Measurement and Exploring Relationships. *Research in Science Education*, *44*(2), 239–266.

Valenzula, A. (2016). *Growing critically conscious teachers: A social justice curriculum for educators of Latino/a youth*. Teachers College Press.

Van Houtte, M. (2005). Climate or culture: A plea for conceptual clarity in school effectiveness research. *School Effectiveness and School Improvement, 16*, 71–89.

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

Weber, K. E., Prilop, C. N., Viehoff, S., Gold, B., & Kleinknecht, M. (2020). Does a video-based practicum intervention provide a realistic picture of classroom management? A quantitative content analysis of the subprocesses of professional awareness. *Zeitschrift für Erziehungswissenschaft*, *23*, 343–365.

Wertsch, J. V. (1994). *Vygotsky and the social formation of mind*. Harvard University Press.

West, C. (1982). *Prophesy deliverance: An Afro-American revolutionary Christianity*. The Westminster Press.

Whitford, D. K., Zhang, D., & Katsiyannis, A. (2018). Traditional vs. alternative teacher preparation programs: A meta-analysis. *J Child Fam Stud, 27*, 671-685.

Wiggan, G. (2007). Race, school achievement, and educational inequality: Toward a student-

based inquiry perspective. *Review of Educational Research, 77*(3), 310-333.

Williamson, T., & Warrington, A. (2019). "Where to take risks and where to lay low": Tensions between preservice teacher learning and program ideological coherence, *Action in Teacher Education, 41*(3), 265-283.

Wilson, S. (2011, October 12). *Written testimony before the house science, space and technology committee subcommittee on research and science education hearing on*. What makes for successful K-12 stem education? A closer look at successful stem education approaches, Washington, DC.

Windschitl, M., Thompson, J., & Braaten, M. (2008). How novice science teachers appropriate epistemic discourses around model-based inquiry for use in classrooms. *Cognition and Instruction*, *26*(3), 310–378.

Windschitl, M., Lohwasser, K., Tasker, T., Shim, S., & Long, C. (2021). Learning to teach science during the clinical experience. *Science Education, 105*(5), 961-988.

Woodbury, S., & Gess-Newsome, J. (2002). Overcoming the paradox of change without a difference: A model of change in the arena of fundamental school reform. *Educational Policy, 16*(5), 763-782.

Wynter-Hoyte, K., Long, S., Frazier, J., & Jackson, J. (2020). Liberatory praxis in preservice teacher education: Claiming Afrocentricity as foundational in critical language and literacy teaching. *International Journal of Qualitative Studies in Education*, 1-22.

Wynter-Hoyte, K., Thornton, N. A., Smith, M., & Jones, K. (2021). A revolutionary love story in teacher education and early childhood education. *Theory into Practice, 60*(3), 265-278.

Yendol-Hoppey, D., Jacobs, J. & Dana, N. F. (2009) Critical concepts of mentoring in an urban context. *New Educator, 5*, 25-44.

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). Sage.

Zeichner, K. (2010). Rethinking the connections between campus courses and field experiences in college- and university-based teacher education. *Journal of Teacher Education, 61*(1-2), 89-99.

Zeichner, K., Payne, K. A., & Brayko, K. (2015). Democratizing teacher education. *Journal of Teacher Education, 66*(2), 122-135.

Zion, M., Schwartz, R. S., Rimerman-Shmueli, E., & Adler, I. (2020). Supporting teachers' understanding of nature of science and inquiry through personal experiences and perception of inquiry as a dynamic process. *Research in Science Education, 50*(4), 1281-1304.

Žižek, S. (2008). *The sublime object of ideology*. Verso.

APPENDICES

Appendix A

Initial Interview Draft

Beginning of Summer 2021

Purpose: The initial interview's goal is to gather information focused on participant's reasoning for entering science education, their background, and thoughts about what it means to be a science teacher. This will be the baseline interview data for this study.

Interview Questions

START: Thank you for joining me today. Today, I will ask you some questions about your journey to this program and your thoughts about science education. Our conversation should be no more than 30 minutes. Do you have any questions for me before we start?

Tell me about when you first knew you wanted to be a science teacher.

What role model do you have for yourself as a classroom teacher?

- What makes _____ a role model?

How do you describe your role as a teacher?

Has there been a defining experience in science for you?

- If so, what is it, and how was it defining?
- If not, why not?

How do you want your students to view science?

What does social justice in the science classroom look like?

On a scale of 1-5, how comfortable are you at implementing aspects of social justice into a lesson?

- What made you say _____?

CLOSING: Thank you for your time. I appreciate the information you have given me. **Is there anything that you would like to add?* *

Interview 2 Draft

August 2021

Purpose: This interview will focus on participants' experiences in the summer semester that have impacted their thinking about science education. Their reflection responses will inform the questions.

Interview Questions

START: Thank you for joining me today. Today I am going to ask you some questions about the summer semester. Our conversation should be no more than 45 minutes. Do you have any questions for me before we start?

Tell me about your experience in the methods class this summer.

What was your most memorable experience this summer?

- What makes it memorable?

- Do you think you have taught a 3D lesson?

How does this way of teaching science compare to how you learn science?

How do you describe your role as a teacher?

Describe a well-organized classroom. When you have your classroom running the way you want it, what is it like?

How do you want your students to view science?

What does social justice in the science classroom look like?

On a scale of 1-5, how comfortable are you at implementing aspects of social justice into a lesson?

- What made you say _____?

CLOSING: Thank you for your time. I appreciate the information you have given me. **Is there anything that you would like to add?* *

Interview 3 Draft

December 2021 or January 2022

Purpose: This interview will focus on understanding why participants made or did not make changes in their teaching. It will be informed by their responses to reflective journals three and four.

Interview Questions

START: Thank you for joining me today. Today I am going to ask you some questions about your experiences this fall semester. Our conversation should be no more than 45 minutes. Do you have any questions for me before we start?

How has this semester been going for you?

How has being in this program influenced your ideas about science teaching?

- What does this look like in your classroom?

How has being in the program influenced your ideas about social justice-focused teaching?

- What does this look like in your classroom?

How do you describe your role as a teacher?

Have you started to think of yourself as a science teacher?

- When did you begin to think of yourself as a teacher?
- Why not?

Tell me about a time you implemented a 3D teaching and learning lesson this semester.

- What went well?
- What would you want to change?
    - Why?

What does social justice in the science classroom look like?

What is the importance of social justice and/or anti-racist teaching in the science classroom?

CLOSING: Thank you for your time. I appreciate the information you have given me. **Is there anything that you would like to add? **

Interview 4 Draft

May 2022

Purpose: The focus of this interview will be to reflect on participants' overall experiences in the program. It will be informed by their responses to reflective journals five and six.

Interview Questions

START: Thank you for joining me today. Today I am going to ask you some questions about your experiences in the program. Our conversation should be no more than 45 minutes. Do you have any questions for me before we start?

What are three words you would use to describe your experience in the teacher prep program?

- Can you tell me more about _____?

What do you believe are your main strengths as a teacher?

How do you describe your role as a teacher?

Can you walk me through your most successful lesson so far this year?

- What made it successful?

Tell me about any challenges you have had in teaching science this year.

- How has your learning in the program supported you in facing _____ challenge?

What was your most memorable experience in this program?

- What makes it memorable?

How do you want your students to view science?

On a scale of 1-5, how comfortable are you at implementing aspects of social justice into a 3D science lesson?

- What made you say _____?

What has helped you become more comfortable with social justice-focused 3D science teaching?
CLOSING: Thank you for your time. I appreciate the information you have given me. **Is there anything that you would like to add?* *

Appendix B

Starting Codebook

Code	Description
PF	*Personal Factors*: Demographic profile, teaching experiences, the nature and extent of preparation to teach, continued learning (general and subject specific), learning experiences
CF	*Contextual Factors*: Cultural and structural contexts TCs work in, collaboration, professional norms, group goals, schedules, physical layout, student and staff demographics, curriculum, mandated assessments and evaluations, textbooks, teaching materials, technology availability and use, budgets, grade levels, departments, the type of school, district, state, and national agendas, principals, mentor teachers, students (beliefs, views, attitudes, conceptions, and expectations students hold about learning and the content topic).
IDE	*Ideology*: broadly accepted set of values, beliefs, myths, explanations, and justifications that appear self-evidently true, empirically accurate, personally relevant, and morally desirable to a majority; appear as common sense, as givens, embedded in language, social habits, and cultural forms that combine to shape the way we think about the world
HEG	*Hegemony*: persuading people to accept the way things are; lived out in our intimate behaviors, glances, body postures, in the fleeting calculations we make on how to look at and speak to each other, and the micro decisions made each day
POW	*Power*: more than interactions in relationships; it is how certain actions modify others; all individuals are vehicles of power
ALI	*Alienation*: a person experiences themselves as estranged from themselves. They do not experience themselves as the center of their world, as the creator of their own acts; distancing of people from the world of feelings and sensuality so that they feel dominated by lifeless objects
LIB	*Liberation*: Overcoming oppression; way individuals a change in the experience the world through thought, language, and art
REA	*Reason*: assess evidence, make predictions, judge arguments, recognize causality, decide on actions where no clear choice is evident; discuss these aspects of reason with others
DEM	*Democracy*: dealing respectfully with difference, live with unresolved conflict, accept that proposed solutions to complex social problems should be viewed as temporary; to relate to others so that power is within and multiplied
TCP	*Teacher Candidate Practice*: the teaching enacted in the classroom
TCT	*Teacher Candidate Thinking*: knowledge and beliefs about their subject matter, knowledge and beliefs about students and how students learn (or should learn), ideas about teachers and teaching (teaching efficacy), thinking about change itself, reflective, planning, and interactive thoughts, concerns teaching, teachers, learning, learners, schools, schooling and subject matter

Appendix C

Responses to "What does social justice look like in the science classroom?"

Participant	June 2021	August 2021	January 2022
Azula	I've had a little bit of a hard time grasping everything that's happening in class. Normally we associate social justice with like history classes or even like language arts classes. I think with science the biggest aspect of social justice is like, not every nerd becomes a scientist. We kind of associate like, 'Oh, these certain people, or these certain races or ethnicities are good at science.'… I want to make sure all of my students know that science is for everyone… So in terms of social justice, it's basically just allowing everyone to be a part of the science community.	I definitely think it means giving a voice to our students who don't necessarily think they are capable of learning or doing science because of systemic issues, like not being placed in a gifted or honors program… because of who you are as a person. I think it's important to have those students be advocates and voices inside your science classroom, for them to understand that they too are capable…They are representing more than just themselves. They're representing my classroom as a whole and the people that they know, the people that they care about, their race, their gender, their class, like their socio economic class… I definitely think it's important to include a lot of diversity in the roles you give to students in your classroom… I think social justice in the classroom is being able to instill confidence all of your students equally in order for them to be to be able to speak on behalf of science.	I think it's allowing my students to be seen and heard equally… [school district] specifically is very white dominant. So, our students who are colored are not seen very often. Making sure that they feel like they are seen and heard a lot more, I definitely think is just my small way of working towards social justice in my classroom. Telling my students that anyone is capable of science, I feel like is extremely important, too… So I guess just being able to make them feel like they fit in to the world of science is my idea of social justice in the science classroom.
Madelia	I'm still trying to figure that out. Because I feel like I can't… the impact would be definitely made	Giving everyone the same opportunity, and a great opportunity as well. The majority of my students are kids of	I guess, based on what I've read about having a class that looks diverse… having a relatively equal mix of White

	more in like a history class. But I'm still trying to figure out how to bring it into a science classroom. And I know [teacher's aide] has been talking about showing different people in different cultures and background in the curriculum so that kids can at least see a piece of their identity... So I'm still figuring out but I know I definitely want to incorporate those things in my lessons going forward.	color. And I want to give them the absolute best experience that I could give them that they probably wouldn't get in another school… the other kids have opportunities to do, but it's because if they're in maybe in a segregated school, maybe their parents have money to send them to the type of school. I want to give my kids that opportunity and not make them feel like they're missing out because other kids getting that and they're not.	kids, Hispanic kids, Black kids, Asian, a general mix of everybody. From different backgrounds and cultures, especially after reading the chapter… it's really eye opening… having those diverse backgrounds provides different perspectives. And thus, you can come up with different discoveries, because you have a different perspective… I really feel like if everyone actually feels like a community, then that would be like a big win for me.
Starr		I guess I think about it is… of the HRL framework the identity piece. Because sometimes even if you don't know something ahead of time, I feel like if you know that someone like you or something that you can relate to, it kind of makes you pay attention versus like, had you not known… When you say, 'Oh, well, they're from so and so or they do this. Oh, I'll do that too, but then it's like, now I'm there.' I feel like that is still kind of hard, because it's like, not being used to that. Then having to find that and make that connection sometimes can be like, 'Whoa.'… Especially when you don't know yourself, you're still making that connection here.	That one... [long pause] I would say... [long pause] looks like to me in a science classroom... [long pause] I really don't know how to answer that one. Like, [long pause] um, Like, [long pause] I feel like my group of students are very open. I don't know if that's already how they are or because of how the tone was already set… like, 'Speak your mind.' I feel like when discussions are had some times…we've had a discussion about Black Lives Matter before and it didn't get too far. I feel like they were open to hearing other perspectives. I haven't had much battle on this… you understand where they're coming from… And each class is different.

Appendix D

Participants Questioning Hegemony through Practice

Participant	Response	Lesson Standards	Learning Objectives	Alignment of Learning Objectives & Activities
Jacob	"I would say… I did a station learning units, where I kind of tried something completely different from what I had been trying, where I was like designing to do something different every day."	**S7L2. Obtain, evaluate, and communicate information to describe how cell structures, cells, tissues, organs, and organ systems interact to maintain the basic needs of organisms**. c. Construct an argument that systems of the body (Cardiovascular, Excretory, Digestive, Respiratory, Muscular, Nervous, and Immune) interact with one another to carry out life processes.	**LO1:** Students will collect data and evaluate it to communicate how organ systems are working together during the performed activities. **LO2:** Students will obtain, evaluate, and communicate information to construct an explanation of how body systems work together to carry out life processes. **LO3:** Students will develop a model and use it to construct an explanation of how body systems work together to maintain life processes	Jacob identified which stations addressed each learning objective and how specific elements of the HRL framework were addressed for each station. LO1: Station 1 (Pulse Rate) & Station 2 (Reaction Time) LO2: Station 3 (Epinephrine), Station 4 (Importance of Vaccines), Station 5 (Building Muscle), & Station 6 (Which organ systems work together?) LO3: Station 8* (Create a Lung: Respiratory System) & Station 9 (Create a Human Hand) *Station 7 was not identified in the lesson plan

Participant	Response	Lesson Standards	Learning Objectives	Alignment of Learning Objectives & Activities
Starr	"I would say the one that stood out to me the most where I feel like… for me and the students was the one were talking about evolution and that we did like this beak adaptation lab."	**SB6. Obtain, evaluate, and communicate information to assess the theory of evolution.** 1. Construct an explanation of how new understandings of Earth's history, the emergence of new species from pre-existing species, and our understanding of genetics have influenced our understanding of biology. 2. Analyze and interpret data to explain patterns in biodiversity that result from speciation	**LO1:** The students will analyze and interpret to **explain patterns** in biodiversity that result from speciation. **LO2:** The students will construct explanations of how new understandings of Earth's history, the emergence of new species from pre-existing species, and our understanding of genetics have influenced our understanding of biology through cause and effect	Starr identified how specific elements of the HRL framework were addressed for the week's lessons. Starr stated, "Students will begin the Battle of the beaks lab where **they will use patterns** to see how the different type of beaks can affect the type of food and how much food a bird can eat." This most aligns with LO1.

Participant	Response	Lesson Standards	Learning Objectives	Alignment of Learning Objectives & Activities
Tam	"Always the most successful is the one that I can show the most demonstration, which is always the electromagnetism and electricity. That lesson is also to be the most applicable."	**SP5. Obtain, evaluate, and communicate information about electrical and magnetic force interactions.** d. Plan and carry out an investigation of the relationship between voltage, current, and power for direct current circuits. e. Plan and carry out investigations to clarify the relationship between electric currents and magnetic fields.	**Identities**: Students will learn about how electromagnet led to the creation of electric motors which influence every aspect of our lives. **Skills**: Students will write scientific report and discuss findings with peers. Students will participate in an argumentation session to evaluate ideas and methods. Students will use multimeter, compass, and trigonometry to gather data. Students will use power supply to adjust voltage and current for the experiment. **Intellect**: Students can explain why there are coils in headphones. Students can explain how some coils are longer. Students can explain why some "magnets" can be turned off and on. Students can explain why copper wire is coiled to make electromagnet.	In Tam's lesson, the alignment between the LOs under skills and intellect can be seen. For instance, Tam has listed in the body of his lesson: "The students will begin their experiment once their proposals are approved. The students will connect the wire to the power supply and position it vertically. The students will punch the wire through a non-conductive horizontal plate and place a compass at a certain distance from the wire. The students will record the angle of deflection form the earth magnetic field and calculate for magnetic force using. The students will record and analyze their data and prepare to form a claim to answer the research question. The students write and submit scientific report then present their finding to their peers. Each group will evaluate other groups' ideas, results, and experimental method. Once the experiment is concluded, the students will derive an equation based on data to describe changes in magnetic field strength by changing current."

Appendix E

Elements of Jacob's First Observed Lesson Plan in Fall 2021

Curriculum Standards
GSE (Georgia Standards of Excellence) / National Curriculum Standards
https://www.georgiastandards.org/Frameworks/Pages/BrowseFrameworks/Frameworks.aspx

S7L3. Obtain, evaluate, and communicate information to explain how organisms reproduce either sexually or asexually and transfer genetic information to determine the traits of their offspring.

b. Develop and use a model to describe how asexual reproduction can result in offspring with identical genetic information while sexual reproduction results in genetic variation. (Clarification statement: Models could include, but are not limited to, the use of monohybrid Punnett squares to demonstrate the heritability of genes and the resulting genetic variation, identification of heterozygous and homozygous, and comparison of genotype vs. phenotype.)

ISTE Technology Standard
https://www.iste.org/standards/for-students

1.3.a. Students plan and employ effective research strategies to locate information and other resources for their intellectual or creative pursuits.

Mode of Instruction
Face to Face / Online Synchronous / Online Asynchronous / Hybrid

Learning Objective/Goal(s)

1. Students will obtain information about sexual and asexual reproduction.
   - Identity: Students will learn how they are a product of sexual reproduction, and how that gives them the genetic variation that makes them unique.
   - Criticality: Students will consider why some people are viewed as lesser despite having no control over their traits.
   - Intellect: Students will gain knowledge about sexual and asexual reproduction.

2. Students will evaluate different organisms' reproductive strategies.
   - Skills: Students will evaluate readings of different organisms to determine how they reproduce.
   - Intellect: Students will learn about the patterns of sexual and asexual reproductive strategies.
   - Joy: Students will be happy to learn about some very unique and strange organisms.

3. Students will recognize and communicate if an organism reproduces asexually or asexually.
   - Skills: Students will verbally communicate which method an organism uses to reproduce.

Introduction or Student Spark (5 minutes)

When the students enter the class, I will have the question, "How is the Civil Rights Act connected to genetics?" Students will be allowed to share their thoughts if they want. I will first ask them if they know what the Civil Right Act is. If no one knows then I will explain what it is to them. I will then ask how genetics is related to segregation before the Act. I will encourage students to ask their grandparents about their experiences in school if they were born when schools were segregated. I will then transition by telling the students that they are the product of sexual reproduction, and that reproduction is the next step into understanding how the twins from the previous lesson. came to be. I will then mention that there are some organisms who reproduce asexually instead of sexually, and that they will be investigating both types of reproduction during class.

Body (40 minutes)

I will begin the transition to the body by introducing this assignment to the students. I will walk around the room and pass out the reproductive strategy organizer while I go through the instructions for the activity. They will be told that they have to fill out their graphic organizer based on the 2 animal profiles that they will be given. Once the directions have been explained and all students have an organizer, I will have them split into pairs. I will give them 3 minutes to pair up and settle in a seat. During this time I will separate pairs who I know will not work well together or be productive. Once everyone is paired up, I will have them turn in their textbooks to page 186 and read through page 188. These pages cover the basics of what sexual and asexual reproduction are, and the different mechanisms of each. While they are reading, I will walk around the class and pass out 2 reproductive strategy animal profiles to each pair, ensuring that 1 is asexual and 1 is sexual. I will then inform the students that they can use their textbooks and laptops to help them find any information that they cannot infer from the animal profiles, and that during the activity, they need to try and recognize patterns for each type of reproduction.. Then they can begin their investigations into their animal profiles and their graphic organizers. They will be responsible for finding the patterns of each type of reproduction through relative complexity of the organisms (including size), the number of parents who contribute genetic information to the offspring, the reproductive mechanism, the relative amount of parental care, and the genetic variation in the offspring. During the activity, I will be walking around

the room assisting any pairs who need help. I will not give away any answers, but I will point them in the correct direction. I will also ensure that they are staying on task and making good progress.
Closure (15 minutes)
When there are 15 minutes in class, I will inform the students that we will be changing gears and moving to the assessment part of the lesson. They will be allowed to stay in their pairs to save time as long as they have behaved well for the activity. I will open up this website, and I will instruct them that as a class, we will go through as many organisms as time allows and decide whether they reproduce sexually, asexually, or both. I will assign one student to be the speaker for the class, and allow them to be the only person who can tell me the class's decision. I will select an organism and read the corresponding description of them. The class will then collectively argue the correct answer together to come up with what they want the speaker to tell me. The speaker will then give me the class's answers, and I will submit their answer. The website instantly tells you if you put in the correct answer. For each question, I will praise the students when they get the correct answer. If they choose the incorrect answer, I will give them a chance to redeem themselves by having a volunteer explain why they were wrong. If no one knows the answer and cannot explain why, then I will explain it to them. This instant feedback helps them in their understanding of sexual and asexual reproduction. I do not think that we will be able to complete all 21 organism examples, but we will do as many as possible before the bell rings. I will also have a volunteer explain the reasoning for the class's answer for every 3rd example. When there are 2 minutes left in class, I will thank the students for their hard work, inform them to keep their graphic organizers in their interactive notebooks to study, and I will tell them that we will be talking a bit deeper about the inheritance of traits.

Elements of Jacob's Last Observed Lesson Plan in Spring 2022

Curriculum Standards GSE (Georgia Standards of Excellence) / National Curriculum Standards https://www.georgiastandards.org/Frameworks/Pages/BrowseFrameworks/Frameworks.aspx
S7L3. Obtain, evaluate, and communicate information to explain how organisms reproduce either sexually or asexually and transfer genetic information to determine the traits of their offspring. b. Develop and use a model to describe how asexual reproduction can result in offspring with identical genetic information while sexual reproduction results in genetic variation. (Clarification statement: Models could include, but are not limited to, the use of monohybrid Punnett squares to demonstrate the heritability of genes and the resulting genetic variation, identification of heterozygous and homozygous, and comparison of genotype vs. phenotype.)
ISTE Technology Standard https://www.iste.org/standards/for-students
1.3.b. Students evaluate the accuracy, perspective, credibility and relevance of information, media, data or other resources.
Mode of Instruction Face to Face / Online Synchronous / Online Asynchronous / Hybrid
Learning Objective/Goal(s)
1. Students will develop and use a model to identify whether an organism reproduces sexually or asexually.. - Identities: Students will recognize the method of reproduction that humans use. - Skills: Students will develop and use a model to communicate whether organisms reproduce sexually or asexually. - Intellect: Students will gain knowledge about sexual and asexual reproduction and how to recognize which mechanism organisms use. - Criticality: Students will remember to fight stereotypes when thinking about the twins with different skin colors. - Joy: Students will find joy constructing knowledge with the whole class and learning how different organisms reproduce.

Introduction or Student Spark (5 minutes)

I will greet the students as they enter the classroom. Once everyone has settled down, I will remind the students of the black and white twins. I will ask them what the twin phenotypes are. Once they have answered, I will ask them if they have the same genotypes or not. Once they have answered, I will tell them that we are going to construct a Venn diagram as a class to further review the similarities and differences of sexual and asexual reproduction. While I am giving instructions I will pass out a Venn diagram to every student. They will be told that it should be kept as a reference to review for the test.

Body (45 minutes)

Students may be given a few minutes to finish their charts from the day before before we create a Venn diagram comparing and contrasting sexual and asexual reproduction. Once we have started the Venn Diagram, I will use a blank template on the projector and ask the class the questions below to fill in the diagram. Students will be told to fill out their Venn diagram template as we go along.

- How many parents?
- Genetic variation in offspring?
- Complexity of organisms?
- Formation of gametes?
- How many offspring?
- Reproductive mechanism?
- Amount of parental care?
- Amount of time needed?
- Similarities?

I will go one by one until the class is confident and comfortable with the answers for each reproductive type. Once we have created our Venn diagram, I will go to Sexual vs. Asexual Reproduction website. This will be the review assessment for sexual and asexual reproduction. Students will be a group with those sitting at their table. I will tell them that each group has to pick a spokesperson. I will tell them that we are going to read some animal profiles and determine if they reproduce sexually or asexually. I will tell them that only the spokesperson for their group can answer, but they should all discuss to come up with that answer. Once I read the profiles I will wait a minute or 2 for the groups to construct an answer. After they answer I will ask them how they know. We will go through as many animal profiles as we can until the end of class.

Closure (5 minutes)

When there is about 5 minutes left in class, I will thank the students for working hard. I will tell them that now they should have a great understanding of the differences between sexual and asexual reproduction. I will tell them that tomorrow we are going to be talking about how organisms who reproduce sexually have more than one copy for each gene because they get one copy from each parent, but that only one gene is expressed. I will tell them that tomorrow we will explore why only one of the genes is expressed and not both.