Learning to Design Student-Centered Equitable Science Instruction: A Case Study of a Social Design Experiment

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Abstract

Equitable science instruction has been interpreted as instruction that recognizes, values and integrates students’ culture and identity within science learning spaces. This is especially important for students who belong to non-dominant communities who have been marginalized by the practices of school and science. By prioritizing students’ cultural practices and experiences, students who are often marginalized in science classrooms are brought to the forefront. Instruction that prioritizes students’ lived experiences are student-centered and therefore equitable because they engage students in science learning that is meaningful and relevant to them and their communities. Despite this need of student-centered science instruction, it is not widespread in science classrooms across the nation.

Another stakeholder in equitable science instruction and an important aspect in achieving the goals of equity are teachers of color because of their shared experiences with students from non-dominant communities and their often expressed intent to teach in culturally-meaningful ways. Teachers of color offer different perspectives and insight due to their own varied experiences and practices and hence are a valuable and essential voice in designing equitable science instruction. A review of literature shows the lack of the voices and perspectives of teachers, especially teachers of color, in the design and adoption of such student-centered science instruction.
The purpose of my study was to understand the process of a teacher of color as he designed chemistry lessons and transformed his instruction to be more equitable. I utilized social design methodology, a design-based approach, to collaboratively design and enact student-centered equitable instruction. I analyzed the teacher’s process to understand his learning and adoption of equitable practices. The outcomes of the study were an instructional model to guide the design of science instruction, description of two sample lessons designed using the model and a description of resources utilized to support the teacher in the design and enactment of these lessons.

The findings indicate that in order to teach science in ways that are student-centered we must build authentic relationships, pursue motives that are relevant and valuable to the student, expand learning outcomes, share cultural and historical aspects of science and reach out to a community of support. The implications for science instruction and teacher preparation are to embrace contradictions as opportunities of learning, engage in critical reflection, consider emotions and well-being as essential aspects of learning and most importantly, challenge deficit notions of students and dominant notions of school and science.
Dedication

I would like to dedicate this dissertation to my community of family and friends back home in India and here in the United States for their constant support and faith in me during this challenging process. I could not have done this without them. Thank you Ma, Pa, Fadhir, Ninoshka, Nikhil, Raisa, Jorge, Isabel, Clifton, Laila, Tanya, Ampili, Sindhu, Sophie, Lawrence, Kevin, Namrata, Sherli, Rebecca, Etienne, Rose, Andre and Robin.
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Chapter 1

Introduction

1.1 Background

The demographic makeup of the United States is rapidly changing and undergoing a “transition to diversity” [Alba and Yrizar Barbosa, 2016, p.917], becoming more culturally diverse due to several factors such as migration, differential birth and death rates, globalization, capitalism, and advances in technology [Colby and Ortman, 2015, Frey, 2015, Nieto, 2014]. A recent report from the National Center for Education Statistics (NCES, de Brey et al., 2019) showed that the current demographic distribution of students enrolled in public elementary and secondary schools during the Fall of 2015 was 49% White, 26% Hispanic, 15% Black and 5% Asian/Pacific Islander.

In contrast to this diversity of the student body, the US education system, its policies, practices, and, in fact, most of the teachers and staff involved, is monocultural, focusing primarily on the perspectives of the dominant community [Escamilla et al., 2013, Grosjean, 2010]. Researchers have recognized that this dominance of school
culture has privileged certain cultural groups and marginalized others [McKinley, 2013, McKinley and Gan, 2014]. This culture of power, representing a set of values, beliefs, and practices, favors certain cultural groups, who are for the most part White, upper and middle class, male, and heterosexual [Barton and Yang, 2000, Del-pit, 1988b]. Students who do not belong to these dominant communities or non-dominant students are viewed and evaluated against this dominant lens and are often seen as lacking skills or knowledge, which is a fixed and deficit view of these students. This deficit view becomes the basis of instructing them in ways that attempt to “fix” what they lack [Gutiérrez, 2016, Ladson-Billings, 2006, Ladson-Billings, 2007]. Non-dominant students are also expected to assimilate into this dominant culture and language in order to academically succeed once again perpetuating deficit notions of their family and their community as not the ‘right culture’. School curriculum is created and instruction is practiced without integrating the non-dominant students’ own cultures and languages, thereby often causing a loss of their cultural identity in the process [Valenzuela, 2013].

Science also can be viewed in a similar way as a culture with its own embedded beliefs, perspectives, practices, and language [Lemke, 1990]. This culture of science is also a culture of power, marginalizing many students, especially non-dominant groups, from meaningful and successful engagement in science [Harding, 1998, Carlone et al., 2011]. How science is defined in schools, taught and practiced in classrooms and who are defined as smart and successful science students are all related to this culture of power, which often favors the learning and practice of privileged groups [Barton and Yang, 2000]. Science is presented as a decontextualized, mechanistic, and static body of facts that has no relevance to students’ personal lives [Brickhouse, 1994, Yager, 1990], which further marginalizes these non-dominant students.
Non-dominant students, who are therefore positioned on the periphery of education systems, are denied access to rich educational experiences in science education [Lee and Buxton, 2008]. They are less likely to have access to high quality curriculum and instructional materials [Basu et al., 2011]. Disproportionately, these students score lower on science assessments and participate less in science classrooms, leading to low representation in science-based professional careers and low graduation rates. They also tend to attend under-resourced schools with deteriorating buildings, underprepared staff and teachers, and classrooms that have few curriculum and instruction resources and outdated texts and have fewer opportunities for participation in summer or enrichment programs [Basu et al., 2011, Lee and Buxton, 2010, Menken, 2013].

1.1.1 Equity for Non-Dominant Students

Equity, within this study, is derived from the work of critical legal scholars and critical race theory, which frames equity from the perspective of non-dominant communities and focuses on underlying historical and cultural structures and practices that contribute to the inequity [Gutiérrez, 2008, Ladson-Billings and Tate, 1995]. I chose this view of equity because it prioritizes the perspectives and experiences of non-dominant communities. Equity therefore is discussed as transforming existing structures or practices that contribute to the inequities non-dominant students encounter in the US science education system and as creating new ones that position the culture and lives of non-dominant students as central to science teaching and learning.

To achieve equity, current reforms in science education encourage cultivating all students’ scientific knowledge and skills in meaningful ways in order to ensure that
all students, irrespective of their cultural background, succeed in science [National Research Council (NRC), 2012]. However, in spite of these reform movements, decades of reports and research continue to show wide disparities in the achievement and success of students from non-dominant communities [Ladson-Billings, 2006, Ladson-Billings, 2007, McKinley and Gan, 2014]. A major indicator of equity in schools is the achievement gap-highlighting differences in academic achievement through differences in standardized test scores of various racial and ethnic groups, graduation rates, advanced placements in courses, administrative practices such as suspensions, and the number of college degrees attained by different ethnic or racial communities [Carlone et al., 2011, Groeger et al., 2018, Ladson-Billings, 2006, Ladson-Billings, 2007]. These numbers continue to show a marked discrepancy between the non-dominant groups and their White peers. These numbers are significant because they shed light on the structures and practices of inequity that exist in education system.

The achievement gap is important to pay attention to because it formed the basis of several educational research studies and policies to find ways that could narrow this gap—beginning from research work conducted in 1980s to present-day policies such as No Child Left Behind Act (NCLB) and Every Student Succeeds Act (ESSA). The attention on the achievement gap also reinforced the importance of supporting all students, especially students from non-dominant communities, to achieve success in standardized tests, graduation, attending college, and having access to a range of well-paid professional jobs. Despite this intent to reform science education to narrow the gap, the inequities remain.

Ladson-Billings [Ladson-Billings, 2006] suggests that one of the reasons the achievement gap remains is that the source of the problem has not been addressed: the social,
cultural, political, and historical structures of inequity, which she terms “educational
debt”, have not been given attention. This educational debt refers to the resources
and practices schools need to provide to non-dominant groups in order to help them
achieve success and reduce the gap. Schooling practices such as segregation, tracking
or out-of-school suspensions, and restrictive educational policies such as high-stakes
accountability through standardized assessments contribute to the maintenance of
this debt and do not adequately address the stark inequalities in the lives of non-
dominant communities reflected by the achievement gap.

The educational debt is also maintained in science classrooms where curricular ma-
terial and instructional practice remains authoritative and ‘culture-free’ focusing on
memorization and understanding of science facts and theories, thereby discouraging
the expression of non-dominant cultural identities in the classroom, maintaining the
education debt. The focus on science content within science instruction and curricu-
lum frames students that come into the science classroom as lacking adequate content
knowledge or skills in science, thereby failing to educate students in additive ways
that acknowledge the skills and knowledge they do possess and can utilize to succeed
in the classroom [Carlone et al., 2011]. Students’ culture and identity are often seen
as factors not relevant to science teaching and learning.

Researchers have shown that the embedded perspectives and unique practices of
school science or even the discipline of science are responsible to this acultural view,
which is transmitted through curriculum and instruction [Aikenhead, 1996, Aiken-
head, 1997, McKinley and Gan, 2014]. The current understanding of science, called
Western modern science (WMS), is a system of knowledge that privileges a universal-
istic view that is embedded in post-positivistic ontologies in which science is conceived
as a practice that is governed by a single set of rules and is culture free [Aikenhead, 1996, Aikenhead, 1997, Aikenhead and Jegede, 1999, McKinley and Gan, 2014]. This universal position, which often discourages individuals and communities from participating in science due to this rigid, one-dimensional view, is viewed as superior and belonging to Western industrial nations and fails to recognize its role in perpetuating oppression [Lyons, 2017, McKinley, 2013].

Therefore, traditional measures of academic achievement such as class GPA or the achievement gap are inadequate for reflecting on and reforming school and science practice because they do not account for cultural, social, historical and political contexts in science teaching and learning. With efforts towards narrowing the gap between academic achievement scores students may reach traditional academic goals, however most students remain disengaged and marginalized because of this school environment that is often *subtractive* [Valenzuela, 2013]. Subtractive practices are those that devalue or “remove” the cultural perspectives, practices, or knowledge that students bring into schools. To cope with these reductive practices, students develop views of school and learning as mere targets to complete for the next step or as irrelevant to their lives. This causes them to disengage, thus failing, dropping out, or not pursuing interests related to science [Carlone et al., 2011, Valenzuela, 2013, Wood et al., 2009].

For equitable instruction, educators need to consider aspects of culture and identity in science instruction [Carlone et al., 2011]. Equitable science instruction aims to produce meaningful learning outcomes that are transformational and sustainable. Equitable science instruction therefore needs to stretch beyond providing students the support they need to understand science content and include attention to stu-
dents’ lived experience, prior knowledge, linguistic and cultural tools, and the ways in which they engage with the knowledge and practice [Gutiérrez, 2016]. This focus on students’ lives must be central when considering equitable instruction.

### 1.1.2 Teaching for Equity in Science and Teachers of Color

To achieve this goal of creating equitable science classrooms through student-centered instruction, science teachers face the difficult challenge of creating equitable opportunities while simultaneously attempting to meet the standards of the state curriculum and high-stakes assessments imposed by district and school policies. Balancing the instruction to draw from the students’ languages and cultures in order to create meaningful experiences for non-dominant students remains a difficult feat but is an essential skill required to achieve the equity agenda [Cushman, 2016, Khong and Saito, 2014, Lee and Buxton, 2010, Menken, 2013].

Teachers of color are an important aspect in achieving these equitable outcomes for non-dominant students [Sleeter, 2001, Zeichner, 2009]. Teachers of color have shown to have a positive impact on the academic achievement of non-dominant students because they serve as role models for these students [Achinstein and Ogawa, 2011], often hold more positive views of schooling [Brown, 2014], and adopt more culturally relevant instructional practices [Villegas and Irvine, 2010].

However, teachers of color are underrepresented in both teaching and in research. The NCES report [de Brey et al., 2019] highlighted that 80% of elementary and secondary public school teachers in 2015 were White. In educational research, most studies discuss teaching and learning from the perspectives of White teachers [Brown, 2014]. From an equity perspective, just as there is a need to support diverse students
in school and science, there is the same need to recruit and support more racial
diversity in the teaching population. Perspectives of teachers of color are also essential
in producing new theoretical knowledge and practice related to the teaching and
learning of science that is inclusive and multicultural. Achieving equity for all students
requires paying attention to the presence and experience of teachers of color and
therefore this study focuses on the experiences of a teacher of color learning to teach
non-dominant students using equitable instructional practices.

1.2 Problem Statement

Research conducted that addresses these issues of equity or studies that discuss
the learning of students from non-dominant communities are often conducted and
written in ways that perpetuate deficit views of students and their home communities,
expressing a need to “fix” them or their community [Gutiérrez, 2016, Ladson-Billings,
2006, Ladson-Billings, 2007]. This view also perpetuates a static view of cultural
practices or traits that assumes there is a fixed “style” of learning associated that is
associated with all individuals from a particular culture [Gutiérrez and Rogoff, 2003].
This potentially leads to the categorization of students into groups that are treated
as homogenous, with all the individuals of that group having fixed characteristics.
For example, students whose native language is not English are grouped together as
a homogenous group of English language learners without accounting for the variety
in the individuals’ past experience, such as their nations of origin, their exposure to
English, and their home communities. There is a need to examine the development of
instructional practice from non-deficit views that value students’ experience in science
instruction.
Recent reform movements in science education standards and curriculum emphasize culture and identity and encourage designing instruction that centers on students’ interests and experience [National Research Council (NRC), 2012]. Science instruction that begins from the knowledge, interests, and experience of students is considered to lead to equitable outcomes [Bianchini and Cavazos, 2007]. However, teachers continue to struggle to translate these views into practice in the classroom [Bianchini et al., 2003].

Researchers and educators have also recognized the need to incorporate students’ lives within science teaching and learning but there has been very little direction on how to go about it. Equitable instruction that is student centered promotes students’ interest and encourages them to pursue science in meaningful ways thus supporting their success in science [Kang and Keinonen, 2018]. There are several models of equitable instruction and curriculum designed. However there is a lack of research that describes and illuminates the process of creating instruction that fulfills this essential goal of equity - centering students’ lives. Student-centered curriculum and instruction are also not widespread in the US education system, and there is a conspicuous absence of teacher and student voices in the design of such equitable science instruction.

There is a call for research that privileges the unique practices and values of students and teachers from non-dominant communities in order to transform instructional practice in equitable ways [Lee and Buxton, 2010]. Therefore, there is a need for equity-oriented research designs that includes teachers’ voices and illustrates teacher learning related to practices that center students’ lived experience within science instruction. It is especially important to include learning perspectives of teachers of
color in order to build such equitable interventions [Kohli, 2009].

1.3 Purpose and Research Questions

The purpose of this study was to develop and understand the design of equitable science instruction for secondary students that integrates students’ knowledge, experience, and strengths thus creating student-centered equitable instruction. In particular, I focused on one teacher’s process of learning to design and develop science instruction that is equitable. The study aimed to support and sustain teacher-led designs in the classroom that engage culturally diverse students in meaningful science learning. My focus of analysis was on the teacher’s learning to recognize and reorganize students’ experience and strengths in order to lead to equitable learning outcomes through instructional practice. Based on this, my research questions were:

1. How did a beginning science teacher of color learn and develop student-centered equitable instructional practices within the space of a social design experiment (SDE)?

2. What were the tensions that emerged as the beginning science teacher of color developed equitable instructional practice in the SDE? How did the teacher negotiate these tensions?

For this study, I utilized the methodology that Gutiérrez and colleagues [Gutiérrez, 2016, Gutiérrez and Jurow, 2016] developed called the social design experiment (SDE). This work unifies design-based research (DBR), culturally and historically based theories of learning, and equity-oriented methods with the aim of transforming social practices through symbiotic relationships with all the participants involved. SDE offers a way to “design for educational possibilities—designs in their inception,
social organization and implementation squarely address issues of cultural diversity, social inequality and robust learning” [Gutiérrez, 2016, page 187]. SDEs create research spaces that respect all the participants’ voices in the design and implementation of this kind of student-centered intervention. This allows us researchers to value teachers and students as equal partners and focus on re-organizing the systems (rather than reorganizing the individual) to design learning spaces that have transformative potential to leverage students’ experience and practices and are sustainable.

An important aspect to note is the use of the word experiment: It does not refer to the experimental or quasi-experimental design common in post-positivistic traditions where the objective is to prove or predict. Instead the word experiment is “reclaimed and reframed as open and creative” [Gutiérrez and Vossoughi, 2010, pg.102], which points toward a collaborative, open-ended, reflective, and innovative process where the goal is social transformation.

1.3.1 A Brief Discussion of Terms

For the purpose of this study I use the terms “non-dominant students” and “students of color” interchangeably. I utilize these terms because they are terms derived from conceptualizations of identity and culture in critical race theory and decolonizing perspectives that inform the perspectives of equity, theoretical framework and methodology utilized in this study [Ladson-Billings and Tate, 1995, Gutiérrez, 2016]. I employ the same framework to identify the teacher in study, who is a teacher of color.

Students and teachers of color belong to non-White population groups. These terms (“students of color,” “teachers of color,” “White”) are related to racial and/or ethnic identities. Race is a social construct that had emerged from discriminatory
scientific practices of validating dominance of one group over the other. In society, it is used to denote different groups based on physical differences, which currently has been debunked by scientists as having no basis in genetics. Ethnicity refers to social groups that share a common ancestry or culture. In this study, I utilize racial and ethnic categories similar to those utilized by the US Census Bureau: White, Black, American Indian or Alaskan Native, Asian, Native Hawaiian or Pacific Islander, and Hispanic or Latinx. Note that the US Census Bureau considers “Hispanic or Latinx” an ethnicity and the remaining categories races. In this study, guided by critical race theory, I utilize these terms, including Hispanic or Latinx, as racial categories. I use Latinx instead of Latino because it is an inclusive term that recognizes the intersectionality of race, gender, and sexuality [Salinas Jr and Lozano, 2017].
Chapter 2

Review of Related Literature

This chapter discusses two major sections of the literature surveyed that contribute to the understanding of this study and the design of the social design experiment. The first section examines research literature that discusses equitable instruction in science. For this discussion, I reviewed equitable instructional models in science education that acknowledge the role of culture in science and learning because my view of equity and learning is informed by frameworks that prioritize culture like cultural historical activity theory, which is the theoretical framework of learning in this study. In my discussion I present a synthesis of research studies and interventions that utilized these instructional models.

The second section focuses on teacher learning and teacher preparation. In this review, I have emphasized beginning science teachers because of the context of study and participant of focus. Beginning science teachers need considerable support [Ladson-Billings, 2001] and can provide insight into how teacher preparation programs can better nurture and retain teachers. My review of literature also concentrates on teachers of color due to the focus of this study. Teachers of color as discussed earlier, have an
important role to play in achieving equity for non-dominant students in science education and their voices are essential in building knowledge around equitable science instruction. This section is also relevant because it informs the teacher support plan I created as part of the SDE (Social Design Experiment), which I describe in detail in Chapter 4, Methodology and Design. It also helps to situate my findings and explore possible implications of my study for teacher preparation.

2.1 Equitable Instruction in Science

Researchers and scholars have unpacked and expanded the definition of equity in several ways drawing from different paradigms, thus contributing to a significant body of literature [McKinley and Gan, 2014]. In science education, equity is seen as a process of creating opportunities for diverse students to participate in science and achieve successful learning outcomes [Bianchini, 2017, National Research Council (NRC), 2012]. Despite the intent for all students to achieve success, inequities still exist because there has been a lack of understanding of the influences and implications of power and privilege that continue to exist in society: The disregard of sociocultural influences on learning and perpetuation of deficit views of non-dominant identities and cultures thus creates an incomplete and ineffective picture of equity [McKinley and Gan, 2014].

In this study, I have used a concept of equity that is derived from critical race theories and critical legal scholarship based on my choice of methodology, the SDE [Gutiérrez, 2008]. SDEs require an explicit focus on equity, and this concept, derived from critical race theory, acknowledges the existence and perpetuation of oppressive systems, emphasizes perspectives of non-dominant communities, and shifts the fo-
cus of inequity to underlying structures that maintain systems of marginalization. Therefore, equity is seen as transformation of systems and structures, rather than non-dominant individuals, which disproportionately marginalize students and teachers of color.

I define equity for this study keeping this perspective in mind. I utilize Lee and Buxton’s [Lee and Buxton, 2010] work on equity and their concept of equitable learning opportunities and Bianchini et al.’s [Bianchini and Brenner, 2009] three-dimensional conception of equity to synthesize a working definition that guides the understanding of equitable science instruction in this study. Lee and Buxton [Lee and Buxton, 2010] propose that equitable learning opportunities are created when science instruction explicitly values the experience that all students bring to their classroom. Bianchini, Dwyer, Brenner, and Wearly [Bianchini et al., 2015] define equity along three dimensions: (1) teachers and teaching, (2) students and learning, and (3) home and community. Their conceptualization of equity along all three-dimensions is student-centered, emphasizing the experiences of and outcomes for students. Equity is enacted through instructional practice that facilitates bridging the gap between students’ everyday lives and the academic world of science, utilizes students’ lives and motivations in science, is derived from non-deficit and dynamic views of student identity and culture, and celebrates the resources from students’ homes and communities. In this study, I define teaching for equity as utilizing practices and creating environments through instruction that acknowledges and leverages the cultural identities of the students in the classroom without holding deficit or rigid views of students’ lived experience.

In contrast to the above perspective, school science is often taught as “culture-free” and in authoritarian ways [Aikenhead, 1996] maintaining teacher-centered practices
that positions the motives of the school, instead of the student, as the center of instruction. This narrow perspective of science in instruction tends to negatively affect students because it does not acknowledge students’ cultural practices and the cultural conflicts that arise due to the practice of “culture-free” science that dominates and causes contradictions. This perspective also narrowly defines how to succeed in science (memorization of immutable body of knowledge) and who succeeds in science (answers correctly, follows rules in the classroom, pays attention, and holds a lot of knowledge or facts) and ignores alternate cultural practices and knowledge [Carlone et al., 2011].

In response to this acultural form of science teaching, researchers and educators have developed several learning theories and models of instruction that acknowledge students’ cultures and leverages them in meaningful ways that can help the students achieve equitable learning outcomes. In the next section, I review instructional models that begin to align with this conceptualization of equity.

### 2.2 Instructional Models Related to Culture

A major concern of science education researchers and educators is the danger of science instruction ignoring or devaluing the cultural identities students bring to the classroom and their practices. Students enter the science classroom with prior knowledge, practices, worldviews, strengths, and skills that have developed from culturally and historically engaging in the practices and perspectives of their cultural groups [Esteban-Guitart and Moll, 2014, Gutiérrez and Rogoff, 2003]. There are several pedagogical models that account for culture of students in instructional practice.
2.2.1 Culturally Relevant and Responsive Pedagogies

Culturally relevant pedagogy (CRP) was introduced by [Ladson-Billings, 1995, Ladson-Billings, 2014] in response to perpetuation of deficit views of students that ignored their experience and cultural identities. CRP contains three major domains of focus: (1) academic achievement-intellectual growth due to classroom instruction, (2) cultural competence-the ability to help students appreciate and celebrate cultural difference, and (3) sociopolitical consciousness-challenge of existing dominant views and utilization of skills to solve real-world problems and become a social change agent. There have been several studies examining CRP in science education in several ways: CRP as a guide for professional development [Chinn, 2006, Grimberg and Gummer, 2013, Mensah, 2011], illustration of CRP in the classroom [Wilson et al., 2017], and assessment of the effectiveness of successful CRP [Johnson and Fargo, 2014].

Upadhyay, Maruyama, and Albrecht [Upadhyay et al., 2017] present a case study examining how non-dominant students utilize their lived experience to engage in science in meaningful ways. The students were in an urban elementary classroom and were from different countries, speaking languages such as Spanish, Creole, Vietnamese, Swahili, and Hmong. Using interviews and observation data over a year, their findings demonstrated that CRP created spaces that empowered students’ voices to influence the science activities, thus making them more student directed. CRP also supported generating the students’ sociopolitical awareness, which is a primary aspect of CRP.

Studies in CRP also include discussions on the congruence (or lack thereof) between school science and students’ culture[Carlone et al., 2014]. Lee and Fradd [Lee and Fradd, 1998] proposed the concept of instructional congruence, which empha-
sizes students’ cultural experience and scientific practices along with the disciplinary demands of science. Pedagogies based on instructional congruence make content and language of science accessible and meaningful to students, leveraging the student’s linguistic and cultural experience. Scientific understanding and inquiry and discourse practices of science are taught using instructional strategies that acknowledge both continuities and discontinuities between school science and students’ experience and knowledge [Lee, 2002, Lee, 2004, Lee and Fradd, 1998]. August et al. [August et al., 2009] utilized this instructional congruence framework to evaluate the effectiveness of an intervention in their creation of Quality English and Science Teaching (QuEST), which was designed to support middle school teachers’ abilities to engage with emergent bilingual students and improve their science and academic language learning. The study showed significant positive gains in science knowledge and vocabulary for students who received the QuEST intervention.

CRP has been utilized to understand and build equitable forms of pedagogy in educational research and teacher education. It has also evolved to support cultural plurality, building multiple, relevant competencies in students [Paris and Ball, 2009]. One of these evolved forms is culturally responsive pedagogy [Gay, 2010], which is defined as utilizing the cultural practices and perspectives of non-dominant students as pathways for teaching them. [Paris, 2012] extended these forms of pedagogies to not only be relevant to students’ cultural experience but also to support the growth of their own communities while simultaneously building their own competencies in the dominant culture.
2.2.2 Funds of Knowledge

Another approach to culturally oriented equitable pedagogy is based on the concept of *funds of knowledge* (FoK) [González and Moll, 2002, González et al., 2005]. The concept of FoK recognizes an individual’s lived experience, especially within the community and family, as sources of useful and powerful knowledge. They are systems of knowledge that develop from historical and cultural aspects of learning. This theory acknowledges the competencies developed from life experience outside classrooms and includes learned knowledge and practices from students’ social interactions, their participation in other social groups, and the various linguistic activities they are engaged in [González and Moll, 2002]. This work emerged from studies of Latinx communities in Arizona and continues to be utilized today to develop equitable pedagogies that engage students from non-dominant communities in STEM fields.

Wilson-Lopez, Meija, Hasbun, and Kasun [Wilson-Lopez et al., 2016] conducted an ethnographic study to explore the relationship between the development and utilization of engineering practices and the FoK of Latinx adolescent youth to support their engagement in the discipline. The researchers primarily made use of interviews and observations and utilized a constant comparative analysis to identify and categorize the participants’ FoK as they relate to engineering. They found that their FoK-especially their familial, communal, and recreational-aligned with engineering practices such as engineering design, systems thinking, ethical reasoning, empathetic reasoning, and knowledge production. The researchers noted an increase in engagement and learning due to meaningful alignment of the two sets of cultural practices.
2.2.3 Border Crossing and Borderlands

Several theories attend to the discontinuities in the cultural difference between community and school science. Aikenhead and colleagues’ [Aikenhead, 1996, Aikenhead and Jegede, 1999, Aikenhead and Michell, 2011] theory on border crossing proposes a learning theory of science that involves students moving between cultures, such as those of culture of community and the culture of school or crossing the borders that bind each sub-culture or culture. Border crossing can be a smooth transitional process when students’ everyday cultures are congruent with those of school science classrooms, and this process is called enculturation. When there is conflict between the two cultures, crossing the border requires students to abandon their home cultures to adapt to and adopt the culture of school and science, leading to assimilation [Aikenhead, 1996]. Students at this junction of incongruence either accept the assimilation or resist it.

Another theory of borders involves Anzaldua’s [Anzaldúa, 2007] work on borderlands. The borderland is a space where different identities and cultures overlap, collide, and/or merge. This space is informed by politics, language, and culture. Students who encounter incongruences have difficulty in the borderlands-struggling to define where they belong or which one to choose. This struggle is essential to understanding that each individual is a hybrid of many selves and that our identities are built at this junction of multiple cultures. Aguilar-Valdez et al. [Aguilar-Valdez et al., 2013] presented three case studies of a variety of learning ecologies that illustrate the transformational potential of pedagogies that acknowledge these border-crossing practices of students and in-between spaces of conflict and opportunity. They showcase how female Latinx students and their teachers in the US cross different cultural borders across language and to bring about equitable science learning outcomes.
2.2.4 Hybridity and Third Spaces


Researchers have conceptualized third spaces in various ways. Gutiérrez et al. [Gutiérrez et al., 1999] conceptualized it as a process that bridges home and school practices that leads to hybrid practices, which have significant consequences for both the social and cognitive development of the student. Their work revolves around learning communities or ecologies that are *diverse, conflictual, and complex*, where multiple voices are recognized and utilized to create spaces that provide students with rich meaningful experiences of collaboration and learning [Gutiérrez et al., 1999]. Such spaces transform conflicts into potential sites for learning [Gutiérrez et al., 1999]. For example, in Guiterrez, Baquedano-López, and Tejeda’s [Gutiérrez et al., 1999] study of hybrid practices, the teacher transformed a situation of potential conflict where the students in the classroom were giggling during the lesson on human reproduction and one of the students used a term considered inappropriate in public spaces. She was able to transform this into a hybrid space by acknowledging the potential taboo on discussing this topic, legitimizing their feelings through humor, and reframing this potentially disruptive and disengaging interaction into a context of successful learning within the constraints of a formal school environment.
Third spaces are seen as equitable science classroom pedagogies that “orchestrate participation” [Gutiérrez, 2008, pg.152], in that they create opportunities for all students to utilize and continue to build their knowledge and practice. This is done through the design and implementation of activities that reorganize the everyday concepts and practices of students into complex, school-based, or “scientific” concepts, leading to transformation of both the individual’s practice and classroom instruction to produce hybrid products and practices. For example, in Gutiérrez’s work [Gutiérrez, 2008] in the UCLA Migrant Leadership Institute, the designers of the learning activity utilized the process of critical autobiography (equitable learning activity) to facilitate the students’ production of a hybrid text and practice. The students began with their stories and life histories and incorporated them into an academic text format, which taught students the elements of academic writing, such as persuasive essays and how to compare and contrast, while also privileging student experience in academic contexts (process of reorganization).

2.3 Learning and Preparation of Beginning Science Teachers of Color

Learning to teach science equitably is a complex and challenging process [Bianchini and Cavazos, 2007]. Two decades ago, Ladson-Billings [Ladson-Billings, 1999] noted the challenge of preparing teachers for diverse student populations. This challenge remains today, and teachers continue to struggle to support and empower their students in equitable ways [Bianchini and Brenner, 2009, Bianchini et al., 2015].

Beginning teachers in particular are vulnerable because of their status as novices who are beginning to develop expertise [Ladson-Billings, 2001, Davis et al., 2006].
Examining and understanding how beginning teachers learn and adopt practices, especially equitable ones, will provide insight into teacher preparation programs for pre-service teachers and induction programs for new in-service teachers that better prepare and support these teachers for the challenges of teaching science equitably.

To better understand how to create environments that support beginning teachers in their development of equitable instruction, researchers investigate how teacher preparation programs contribute to teacher learning. Due to the situated nature of learning, teacher learning is most often explored in the context of teacher education. [Bianchini and Brenner, 2009] investigated how an induction program supported and/or constrained science teacher learning of equitable instructional practice. They found that the induction program did not adequately support teacher learning for equity; rather, previous experience from their teacher preparation and their teaching community played a larger role in teacher learning.

Within the literature on teacher learning and teacher preparation, the focus on teachers of color has been lacking. There have been only a few studies that examine the learning and preparation of teachers of color in the literature, and it has been almost non-existent in science education literature [Sleeter, 2001]. In one of the few studies found, Mensah and Jackson [Mensah and Jackson, 2018a] analyzed the experiences of pre-service teachers of color in an elementary science methods course. Utilizing critical race theory and the lens of “science as White property,” they found that when provided with equitable learning opportunities within their schooling and teacher education experience, teachers of color can challenge and defeat cycles of alienation, exclusion, and inequity in science, which they often encounter during their schooling and higher education.
Teachers of color are essential to achieving goals of equity in science education, especially for non-dominant students. Teachers of color can be a valuable resource to students of color due to shared experience or “cultural synchronicity” [Villegas and Irvine, 2010]. The shared understandings of cultural experience can become an effective teaching strength [Philip et al., 2017]. Achinstein, Ogawa, Sexton, and Freitas [Achinstein et al., 2010] conducted a review on the retention of teachers of color and noted that teachers of color tend to work and stay in schools that have high proportions of students from non-dominant communities. In another review, Villegas and Irvine [Villegas and Irvine, 2010] noted that teachers of color serve as role models to all students, especially students of color. In a quantitative study, Oates [Oates, 2003] found that teachers of color have higher expectations of students of color. This study utilized mathematical modeling to analyze data and compare the effects of White teachers’ perceptions of Black and White students’ performance on standardized tests and compared the impact of Black teachers’ perceptions on the performance of the two cultural groups of students.

Teacher education and support programs play an important role in the preparation of teachers of color for equitable science teaching [Sleeter and Owuor, 2011]. Souto-Manning and Cheruvu [Souto-Manning and Cheruvu, 2016] examined the impact of a teacher education program on the beliefs, practices, and identities of six early childhood teachers of color. They observed the teachers during their teacher program and the first three years of their teaching. They found that teachers of color challenged the dominant institutional discourse and appropriated these discourses, reframing them in agentic ways. These positive experiences are not common. Brown [Brown, 2014] conducted a critical review of the literature on the preparation of teachers of color in order to understand the challenges that teachers of color encounter in teacher
educator programs and demonstrated how the dominant discourse of Whiteness that remains embedded in teacher educator programs hinders the preparation of teachers of color in meaningful and relevant ways. Gomez, Rodriguez, and Agosto’s [Gomez et al., 2008] study found that female Latinx teachers of color experienced low expectations and a cultural mismatch with their faculty, staff, and peers in a predominantly White institution.

Beginning teachers of color also face similar challenges during their first few years of teaching. Teachers of color leave the field at a much higher rate than White teachers [Ingersoll et al., 2017], but there remains a lack of literature on the experiences of beginning science teachers of color (Jackson & Kohli, 2016). Achinstein and Ogawa [Achinstein and Ogawa, 2011] conducted a longitudinal study of 21 beginning teachers of color working in urban schools and engaged in social justice-oriented teaching. The findings of study show that urban schools are unsupportive toward teachers of color and restrict the agency of teachers of color through limiting access to supportive colleagues, discouraging talk about race, restricting their roles in the school, and insisting on adherence to reductive curriculum and instructional practices. Kohli [Kohli, 2018a] analyzed the narratives of 218 teachers of color that served in urban schools and were oriented toward social justice, confirming the findings in the previous studies: Urban schools with high diversity in student population remain spaces with hostile racial climates. Teachers of color at these schools often encountered racial micro aggressions and/or were negatively affected by the color-blind policies and practices of these schools, which stunted their professional growth and did not encourage them to remain at these schools.
To counteract these hostile spaces, teachers of color have developed different practices to enable themselves to thrive. Lee [Lee, 2013] qualitatively explored the experiences of eight teachers of color in suburban high schools, finding that the teachers of color performed and constructed their identities in ways that rejected stereotypical images of their cultural group, avoided the prejudiced biases of their peers and staff, and separated their personal lives from their professional ones, leaving “their cultural selves outside of school” (p. 10). Kohli [Kohli, 2018b] analyzed the experiences of veteran female teachers of color in order to offer insight into their teacher preparation, finding that the teacher education programs these teachers of color attended did not adequately prepare them to be successful in the schools’ hostile racial climates. Instead, they created collective, self-led (i.e., teacher-led) spaces in which they were able to develop racial literacy, which helped them remain in the field.

2.4 Conclusions: Gaps in Supporting Teachers of Color for Equitable Instruction

The review of the research literature shows that despite advancements in theories and models of equitable instruction and its inclusion in teacher preparation, it remains confined to innovative or informal spaces that lie outside the mainstream in schools. The professional learning spaces that provide teachers support for equity are also often led by external entities such as universities, districts, schools, or even researchers/teacher educators-teacher and student voices are often absent in the design and discussion of how to teach equitably. A common practice among all models has been, to deliberately and explicitly value and incorporate student lives in instruction. However, this aspect of equitable instruction has been underdeveloped.
Another important point to note is that there is a paucity of research that illustrates or discusses how teachers of color learn and develop equitable science practices due to the prevalence of the dominant (i.e., White) cultural views and practices in teacher education [Mensah and Jackson, 2018a]. This dearth of research is also reflected in the absence of these discussions at the secondary science level. There is a need to understand the learning and experience of teachers of color, especially given that they often face challenges exacerbated by their cultural membership to non-dominant groups throughout their teaching career.

In order to transform practice intro equitable practice, it is necessary to begin with students’ life experience, understanding and extending their skills and knowledge, thus prioritizing their well-being [Bianchini and Cavazos, 2007]. When designing curriculum and instruction beginning with student experience is important because it engages students in meaningful ways. This provides spaces for them to learn and perform successfully in academic environments and pursue their own goals of success in science. More importantly, it reduces the inequities of the educational system and the power structures in place in schools and science classrooms. It addresses these inequities because it positions student experience in the forefront of curriculum and instruction, thereby becoming more inclusive, inviting and, therefore, equitable.

To complete the equitable instruction agenda, for equity in science education, prioritizing teachers of color in teacher education programs and in schools is essential to achieving the goal. In order to contribute and expand this body of research and knowledge, we need more studies that help develop deep and complex understandings of teacher learning of equity, especially the learning and other processes of teachers of color.
Chapter 3

Theoretical Framework

In this chapter, I discuss the theoretical framework, cultural-historical activity theory that informs the design of the study and perspective of learning. I begin with a brief review of the theory and its essential concepts.

3.1 Cultural-Historical Activity Theory

The cultural-historical activity theory (CHAT) was derived from the works of Vygotsky and then later developed by his students Luria and Leontiev. Current scholars involved in developing the theory are Michael Cole, Yrjo Engeström, Jean Lave, and Barbara Rogoff [Roth and Lee, 2007].

CHAT emerged as a new way of looking at learning. Prior theories focused the attention of researchers on examining learning independent of the context of development. The heavy focus on knowledge as a form of cognition that was internal and only involved thinking “within the mind” pushed researchers to reconsider these theories for those that included interactions with the real world [Eijck and Roth,
Knowledge is enacted in practice and therefore cannot be independent of human activity and interaction. In CHAT, human activity became the focus of learning because of the dependent role of activity on learning. Activity is also grounded in the cultural, historical, and material aspects of life and hence CHAT [Eijck and Roth, 2007] also considered these contexts of development.

Due to the context of development within which learning takes place, cognition is understood as distributed beyond just the thinking mind across several aspects of the environment and the individual, which include the motives of the activity, role of the body in the activity, and the tools provided to accomplish the motives. Any human activity, for example farming, schooling, or governing, is also a collective process that occurs to fulfill a societal need; therefore, knowledge is no longer confined to the minds of individuals but is present in the actions the individuals of a community take to conduct an activity as a group. Cognition, again, is distributed among actions of other members of the community participating in the activity of learning and the rules of the community enacted within the learning space.

I utilized three main concepts of this theory to define and further describe learning and its contexts of development: (1) the activity system, (2) expansive learning, and (3) repertories of practice.

### 3.1.1 The Activity System

CHAT was conceived to focus on collectively motivated human activity. Activity is a cultural and historical formation that comprises goal-direction actions performed to meet the collective needs of humans in communities or society [Roth et al., 2009]. For example, weaving fibers or teaching children serve to meet a collective
need of society: clothes and dissemination of (cultural) knowledge, respectively. Human activity is a system composed of individual moments, forming structural parts of this system and understood in relation to other moments of this system and within the context of the whole activity. The structural aspects of the activity and their relationship with each other and the whole are denoted in the form of a triangle (Fig. 3.1.1).

Deriving from the Marxist theory of dialectical material, which is an understanding of parts of a whole in relation to the whole and its other parts, scholars developed the activity triangle to reveal the various social and material interactions significant to the activity system, representing the various moments or structural aspects of an activity [Engeström, 1987]. Figure 3.1.1 depicts this activity system as the activity triangle. I utilize this structure of activity to inform the design and analysis of the study’s instructional model and lessons. The triangle provides a list of all resources to be considered when designing spaces for robust learning [Engeström, 1987].

Figure 3.1.1: Model of activity system from [Engeström and Sannino, 2010]

The various moments within the activity are:
Subject: This moment refers to the individual or subgroup whose position and point of view is chosen as the perspective of the analysis, such as an individual student or the teacher.

Object: This refers to the individual’s and community’s motivations. The object is turned into outcomes with the help of instruments that include tools and signs utilized during the activity to mediate the process of teaching and learning, such as laboratory equipment and disposition for writing lab reports [Andrée, 2012]. Objects are important because they orient the activity [Roth et al., 2009]. Learning occurs are subjects take up and enact actions to accomplish the particular goal of the activity as a person’s possibility of action increases [Roth et al., 2009]. Therefore, it is essential to identify the motives of the activity that the subjects are engaged in to ensure expansive learning. The motive of the activity is the primary goal that fulfills the societal need and is different from the motives of individual actions or tasks. For example, within a science classroom, the primary motive of teaching and learning (activity) is the dissemination of the cultural knowledge and practices of the scientific community. Teachers take up actions to achieve this primary goal; however, their goal could be students’ understanding of a scientific phenomenon, which in turn fulfills part of the larger societal need.

Community: This part of the activity refers to the individuals and subgroups that share the same general object and engage in the activity. In the classroom, the community is the teacher and students. This community could expand to include other members such as parents, local community leaders, other teachers, and school administrative staff such as counselors or the principal. The community is defined by the object of the activity and the subjects participating in the
activity.

Tools: This moment is a significant aspect of the activity as it forms the mediator of the actions performed. Tools consist of artifacts, both symbols and materials that shape the way subjects interact with their environment and other members of the community [Cole and Engeström, 1993]. Tools can understood as simply as things such as a notebook, measuring beakers, smart boards, or a camera. However, the most significant mediator is culture.

Culture is understood a set of artifacts inherited from participating in the cultural communities to which one belongs [Gutiérrez et al., 2009]. These artifacts become tools through which the subject accomplishes the goal. Within an activity, cultures of individuals along with the items present in an environment mediate the actions taken up by the subject to accomplish the goals and therefore influence the modes of participation of an individual.

Division of labor: This refers to horizontal division of tasks and vertical division of power and status. This element provides information regarding the roles and actions of the teacher and the students as they engage in the activity. This division relates to distributing different tasks and responsibilities among the community (horizontal) but also recognizes the unequal distribution of power and status among the members of the community (vertical). For example, the teacher is often considered to have authority over students, or White students are viewed as academically competent compared to Latinx students who are emergent bilinguals. Recognition of these divisions can help lead to equitable outcomes and practices so that the tasks of the activity are divided in ways that reconstruct the hierarchical relationships between the members of the community in or-
der to decentralize power and authority in the classroom (vertical) and reject deficit assumptions of the importance of tasks and competencies of the students (horizontal).

Rules: This moment refers to the explicit and implicit regulations, norms, conventions, and standards that govern or influence the actions performed within the activity system [Engeström and Sannino, 2010]. Similar to the division of labor, rules of the activity relate to power. The norms and conventions governing an activity are often derived from dominant perspectives, marginalizing non-dominant perspectives and homogenizing spaces. These rules are also tend to be implicit, resulting in individuals from non-dominant backgrounds not being included and seen as “failing” to follow the rules of the dominant community.

3.1.2 Expansive Learning

Expansive learning [Engeström and Sannino, 2010] is grounded in CHAT and the metaphor of learning within CHAT is that of “expansion,” where learning is viewed as extending one’s possibilities of action while pursuing one’s own goals and motivations [Roth and Lee, 2007]. This extension is the development of agency: extending the possibility of acting in the world to pursue goals and expanding the power to act in the world to transform it in ways that are meaningful to the subject (Holzkamp, 1993). Learning occurs as we engage in activities with motives that are relevant and meaningful to us. Therefore, the motives of the activity influence how people participate and consequently what they learn [Roth et al., 2009]. Activities that have expansive objects-motives that expand an individual’s possibilities and power of action-encourage expansive learning.
Another important aspect of expansive learning is the view of learning as change in participation. The process of learning is seen as participating in and changing forms of this participation in activities of the cultural communities valued by the individual using skills and knowledge the individual has developed culturally and historically [Gutierrez et al., 2007]. This process involves reconstructing existing practices and knowledge to construct new methods and knowledge that expand current learning motivations and current practices to deal with new problems that arise in the daily activities of individuals. Therefore, learning is seen as the construction of new objects and new activities where the everyday concepts of the student are reconstructed into more complex academic concepts [Engeström and Sannino, 2010, Roth and Lee, 2007]. The emphasis in expansive learning is the development of “historically new forms of activity, not just socially existing or dominant forms as something new” ([Engeström, 1987, p.30] cited in [Gutierrez et al., 2007, p.69]).

From this perspective, teaching involves facilitating opportunities of learning that introduce new and even unfamiliar ways of doing things to reconstruct existing practices and develop agency, thus extending students’ experience. As a result, students have ongoing opportunities to assume new roles and learn new approaches that enable them to successfully navigate the world.

An example of such a reconstruction is the hybrid critical autobiography activity described by Gutiérrez [Gutiérrez, 2008]. The instructors leveraged students’ lived experience of migration and reconstructed the students’ current practices of writing to develop academically expected formats, such as the persuasive essay. This leads to equitably successful outcomes of academic achievement, student engagement, respect and incorporation of students’ hybrid practices, and development of agency to engage
with issues of migration and marginalization.

Expansive learning supports both horizontal and vertical forms of expertise [Gutiérrez, 2008]. Traditional learning theories and perspectives focus only on vertical learning, where development occurs in a single direction from novice to expert or immaturity or maturity. The priority in vertical forms of learning is the accumulation of knowledge over time [Engeström, 2001]. Horizontal forms of learning, on the other hand, are individuals’ construction of knowledge as they traverse across different and varied contexts. As individuals engage in different practices across different cultural communities, they develop a set of tools that enable them to utilize these tools in other communities and contexts to successfully engage in the world. Expansive learning occurs when these tools are leveraged and expanded. These tools are an important aspect of understanding learning and are explained in detail in the next section.

3.1.3 Repertoires of practice

In order to recognize and understand the unique experience and practices of students in non-deficit ways, I utilized the concept of repertoires of practice [Gutiérrez and Rogoff, 2003]. Participating in different cultural practices creates opportunities for students to develop skills, or a toolkit of practices. The toolkits that people acquire as they participate in multiple practices of different cultural communities are called repertoires of practice [Gutiérrez and Rogoff, 2003]. For example, students who belong to communities that historically value oral over written literacies engage in story-telling practices, thereby developing their communication, language, creativity, and memory as essential tools to that can be used to achieve goals. If we only think in terms of binaries such as home/school or formal/informal, then we miss the “horizontal” expertise that people develop, such as what is learned as children translate for
their parents across business institutions, traverse national borders, provide sibling care, and negotiate new cultural practices [Gutiérrez and Rogoff, 2003].

The notion of repertoires of practice captures both vertical and horizontal forms of expertise: This includes not only what students learn in formal learning environments such as schools, but also what they learn while participating in a range of practices outside of school.

This toolkit represents culture: Our interactions with the world are mediated by culture. The possibility of acting, the power of the action, and ways of acting are dependent on the cultural communities we belong to and the tools we appropriated from this membership. Learning, individual development, and characteristics are now understood within cultural and historical contexts: Patterns of people’s practices or approaches in a given situation are discussed without reducing them to fixed traits or stereotypical cultural characteristics, such as the categorization of all Latinx students as most likely emergent bilinguals or immigrants, which reduces the Latinx identity and encourage teachers to only focus on this fixed trait, often defined from a deficit perspective.

These patterns of practices become an individual’s toolkit from which they choose appropriate or best-suited practices to achieve the goals of the activity or their own motivations. Expansive learning involves expanding this toolkit to extend the possibility and power of actions. Hence, an important feature of focusing on repertoires is encouraging people to develop expertise in determining which practice from their toolkit can be under certain circumstances, especially those that involve power and oppression [Rogoff et al., 2003]. An example of a potential repertoire of practice is a common strength discussed in the research literature for bilingual students: the
practice of switching between languages effortlessly and quickly to navigate spaces that are familiar or strange [Marian and Shook, 2012].
Chapter 4

Methodology

4.1 Overview

The purpose of this study was to design and analyze the development of inclusive science instructional practice that originates from and extends the learning experiences of students. However, such intervention-based studies are often traditionally led by the motivations of the researcher or exclude the voices of the teachers and students for whom the intervention is designed. These interventions also may perpetuate deficit views of non-dominant students by designing interventions that aim to “fix” their learning rather than respect and expand it [Gutiérrez, 2016]. For these reasons, I chose a methodology that not only facilitates the design of an equitable intervention but also does so in equitable ways. As Gutiérrez states in her 2011 AERA Presidential Address [Gutiérrez, 2016], “we need models for educational interventions that are consequential—new systems that demand radical shifts in our views of learning and in our perceptions of youth from non-dominant communities so that they can become agents of newly imagined futures” (p. 187). We need interventions that utilize new perspectives of teaching and learning science that place students at
the center of instruction.

The SDE, developed by Gutiérrez [Gutiérrez, 2008, Gutiérrez, 2016] and colleagues, is a methodology that is both an “equity-oriented research agenda and [equity-oriented] project” [Gutiérrez, 2016]. Thus, I chose the social design methodology to design equitable science lessons and instructional model collaboratively with the participating teacher, while also facilitating opportunities to reflect on and transform his instructional practice.

I have organized this chapter into four sections: (1) a description of the methodology of an SDE; (2) the research design, organizing the study into three phases; (3) a description of the goals and design elements of the SDE; and (4) the research methods, detailing the participants, context, data sources collected, process of data analysis, and methodological rigor.

4.2 Social Design Experiments (SDEs)

SDEs are an approach to DBR that is created with a new “social imagination” [Gutiérrez, 2016, p. 188]. SDEs are utilized to create change in inequitable systems in order to reorganize structures to support non-dominant communities. This methodology allows researchers to simultaneously create change and study it [Gutiérrez, 2016]. SDEs are informed by interventionist DBR (Design-Based Research Collective, 2003), formative experiments [Engeström, 2008], learning theories from CHAT and views of equity [Gutiérrez, 2016].

Formative experiments and DBR are methodologies often employed in educational research and are utilized to study phenomena in authentic learning environments.
These research methodologies were developed as an extension to conventional laboratory experiments, where researchers study phenomenon in non-contextual ways [Reinking and Bradley, 2008]. From a sociocultural and CHAT perspective, learning occurs as individuals interact with one another and their world, mediated through their cultural artifacts. Therefore, DBR and formative experiments were developed to design educational interventions that accomplish a particular goal in authentic settings, such as within a classroom [Reimann, 2011]. SDEs belong to the same class of methodologies that aim to explore and analyze teaching and learning while taking into consideration the contexts of development.

The characteristic feature of these forms of methodology that remains in SDEs is the continuous modification of the intervention formatively during its implementation in response to observations made and data collected. SDEs, like DBR and formative experiments, are iteratively implemented, where cycles of reflection, refinement, and repair occur over the course of the experiment [Gutiérrez, 2016, Reimann, 2011]. However, SDEs differ from design and formative research due to their explicit focus on historicity and equity. Through SDEs, researchers engage in an interventionist way in non-dominant communities to empower the stakeholders involved and develop a historical perspective, thereby understanding the social, cultural, and historical influences in their learning. This enables the stakeholders involved to tackle and challenge the inequities they encounter and transform into “learners and agents of social change” [Gutiérrez, 2016, p. 192].

Equity and historicity are at the heart of social design of learning environments and interventions. Gutiérrez [Gutiérrez, 2016] provides key features that characterize this methodology: (1) attention to history, (2) focus on re-organizing the activity or
system rather than the individual, (3) utilization of dynamic models of culture, (4) emphasis on equity, and (5) emphasis on sustainable transformation.

The goal of an SDE is to develop “historical actors” [Gutiérrez, 2016] who learn to perceive events and actions from a historical perspective. From this perspective, one comes to understand how particular cultural practices came into being and how they enhance or limit opportunities for learning [Gutiérrez, 2008]. Within this study, the researcher and teacher constantly explored issues of schooling and science instruction from a historical perspective during the teacher support sessions in order to understand the need to transform current science instructional practices and view students from non-deficit perspectives, focusing on their histories of engagement in different practices in their everyday life. We also attempted to include a historical perspective in the lessons we created, co-designed by the teacher and researcher with student input, in order to help students understand the effects of nuclear energy and the practices of the scientific community. Finally, this study was designed after conducting a literature review in order to understand the historical background of science education and teacher education when developing the SDE.

Another essential aspect of the SDE is the focus on the reorganization of the activity rather than the participants. Utilizing a cultural-historical perspective, the SDE creates opportunities to participate in alternate and multiple ways that enable expansive learning within individuals. Here “design” is seen as a “re-mediating activity”—deliberately changing the instruction and redesigning the learning environment to create opportunities for individuals to engage in robust learning [Gutiérrez et al., 2009, Gutiérrez and Vossoughi, 2010]. Re-mediation, therefore, is seen in a new light: not in a deficit manner as “remedial learning” to “fix” the student, but rather as a
way of changing the learning environment into a place where all students can expand their repertoires of practice and challenge existing inequitable practices and norms [Gutiérrez and Vossoughi, 2010]. This study aimed to support non-dominant students and the teacher of color by focusing on science instructional practices and curriculum that leverage their strengths and utilize their experience to make meaningful connections rather than on practices designed to “fix their inadequacies.”

SDEs are created to help educators move away from deficit notions of students’ identities and cultures. Just as re-mediation is reframed to view students in non-deficit ways, within SDEs, educators and researchers employ dynamic models of culture instead of fixed and deficit notions. In SDEs, culture is not seen as a set of fixed characteristics that reside within an individual [Gutiérrez and Rogoff, 2003]. Instead, culture is a social inheritance that comprises a set of artifacts, both symbolic, such as language and oral practices, and material, such as literature and clothes. These artifacts are created as individuals come together to transform their environment through their participation in activities that fulfill the collective need. Culture becomes the mediator through which we interact with others and our non-human environment [Cole and Engeström, 1993].

From this perspective, cultural characteristics of individuals are seen through the lens of historical engagement in practices. Cultural differences are variations in people’s engagement in everyday practice [Moll, 2000]. This shifts the focus from deficit notions of right or wrong ways of learning to the cultural repertoires of practice students utilize to engage in the activities. The teacher and researcher utilized this view of culture to develop lessons that could be used to leverage students’ strengths rather than focus on their weaknesses. The researcher also utilized this strengths-based view
to analyze the teacher’s development of practice.

As stated earlier, what distinguishes SDEs from other methodologies is its explicit focus on equity. For the SDE, the first question we must ask is “How is equity accounted for across the inquiry project? Is it locally defined and experienced?” [Gutiérrez and Vossoughi, 2010, p. 103]. This study was designed because the teacher and researcher both desired to enact more equitable practices within the classroom and the study. The researcher, building from literature and co-constructing with the teacher, created notions of equity in science education as instructional practice that place students’ lives and their motivations as the center of teaching and learning. In order to continue focusing on aspects of equity that support non-dominant groups, the researcher collaborated with the teacher and students to bring in their voices to the purpose and design of the lessons. The teacher was involved in the setting the goals, designing artifacts and lessons, implementing these artifacts, and modifying the artifacts.

The collaboration in the SDE transforms all the stakeholders involved, including the researcher. This transformation involves a change in the learning environment through change in the “methods, tools and dispositions, as well as the relations with participants in the focal activity” [Gutiérrez and Vossoughi, 2010, p. 102]. Related to re-mediation of activity, transformability is a characteristic of SDEs where new systems of practice are created when the current system is unsustainable [Walker and Salt, 2006].
4.2.1 Case Study of an SDE

Stake [Stake, 2005] states that a case study is “not a methodological choice but a choice of what is to be studied” (p. 443). The methodology chosen in this study is the SDE. However, due to the scope of this study and the choice of what is studied here, I embedded a case study design within the SDE. The first step in a case study is the identification and binding of a case, which is to define what the case is. A case is viewed as a social object existing in reality with defined boundaries [Schwandt and Gates, 2017] and can represent anything: a person, an event, a location, or even a country. In this study, I focus on the practices and reflection of a single teacher as we both engage in an SDE to design equitable chemistry instructional units. The SDE was a smaller space created separate from but within the main semester system of the school and classroom. The focus of a case study is about understanding all the nuances present within that particular case. Therefore, my research questions and analysis concentrate on understanding the complex process of learning of a single teacher and his development of practice to understand and provide insight into the process.

4.3 Research Design

SDEs, as discussed above, are derived from and inspired by the works of leading authors in DBR such as Ann Brown, Allan Collins, Paul Cobb, and Koen Gravemeijer [Brown, 1992, Cobb et al., 2003, Collins, 1992, Gravemeijer, 1994, Gravemeijer, 1998, Gravemeijer, 1999, Gutiérrez and Jurow, 2016, O’Neill, 2016]. In keeping with this pattern, I utilize Gravemeijer and Cobb’s [Gravemeijer and Cobb, 2006] framework of conducting design research to outline my research study, as SDEs follow the same iterative and reflective process of DBR. The researchers propose three phases
of research design: (1) preparing for the experiment, (2) experimenting in class, and (3) conducting retrospective analyses. I utilized these three phases to conduct and present my study and findings in an organized manner that is easy to follow. In this study, I used qualitative methods to conduct the case study of the SDE. I have situated these methods within these phases, maintaining the essential characteristics of SDEs. I have provided an illustration of how the three phases are conducted and related to each other in the Appendix B. A summary of the three phases is provided in Table 4.3.1 below.

### 4.3.1 Phase 1: Preparing the Experiment

The object of this phase is to construct a “local instruction theory,” which includes the instructional activities to support learning, a vision of the classroom culture, the role of the stakeholders involved, and an inferred process of learning of the students [Gravemeijer and Cobb, 2006]. This local instruction theory is then expanded on and revised during the implementation of the intervention. This theory thus becomes the guiding intent or “lens” of the study and intervention. The authors suggest that a way to construct this local theory is to establish instructional endpoints and starting points.

The instructional endpoint typically forms the goals of learning and research. These goals are not merely goals of a particular institution blindly taken up but instead are constantly problematized, clarified and revised from a disciplinary perspective to ask “what the most relevant and useful goals are” [Gravemeijer and Cobb, 2006, p. 20]. The instructional starting points are constructed by reviewing research literature and other resources, such as curriculums and science textbooks. Gravemeijer and Cobb [Gravemeijer and Cobb, 2006] also suggest pairing this literature/document review
with a form of assessment, such as written tests or interviews that aids in identifying a starting point.

During this phase, I conducted semi-structured interviews to better understand the teacher’s views of equity, his goals for transforming his instruction, and the possible roles of all participants in the design, including the students. The goals of the experiment were built from both the teacher’s and the researcher’s desire to transform science instructional practice to better serve non-dominant students in the classroom. We also began to informally plan potential units to transform during the SDEs and ways in which we would transform instruction. I began to create a teacher support plan to help the teacher engage in theory learning, theory translation, and reflection. At the start of the study, to build the local instructional theory, we utilized a guiding question and our notions of student-centered equitable instruction to design the lesson. The guiding question was “How do we incorporate and expand students’ repertoires of practice in science instruction to teach in equitable ways?” The local instructional theory also utilized the CHAT framework of learning derived from the research literature.

4.3.2 Phase 2: Experimenting to Support Learning

This is the implementation phase of the design experiment. The purpose of this phase is to extend and improve the local instruction theory and to develop an understanding of how learning occurs, framed within this local theory [Gravemeijer and Cobb, 2006]. SDEs, such as DBR, are characterized by multiple cyclic processes of practice and reflection. To achieve this, during the implementation of every lesson and after, the researcher analyzes the participation and learning processes of the participants. They then make decisions about the local instruction theory, revising
it to address the specified aspects of the design and achieve the goals of all the participants involved. This process of implementing, analyzing, and revising can be seen as a microcycles [Gravemeijer and Cobb, 2006]. Gravemeijer and Cobb [Gravemeijer and Cobb, 2006] also consider “macrocycles” of analysis significant to the process of developing and revising the local instruction theory. These macrocycles involve longer durations of time that focus on the development of the local instruction theory as a whole.

Therefore, there are two levels of analysis: one at the level of the individual activity or lesson and the other on the design of the intervention/curriculum as a whole. This often spans the entire experiment and informs the next iteration of the implementation. During this phase, we planned and implemented two chemistry lessons based on our initial conversations and preliminary models. Each unit served as an iterative macrocycle to revise instruction between the two units and each debriefing session served as an iterative microcycle to revise instruction within the same unit. I conducted video recordings of the classroom during instruction, aided the teacher in instructing and implementing the lessons, and continued to build the teacher support plan based on the reflection and debriefing sessions, which were also recorded. These microcycles involved debriefing sessions with the collaborating teacher to develop the shared interpretations of the analysis and revisions that are essential to SDEs. I collected all student and teacher artifacts produced during the two iterations.

4.3.3 Phase 3: Conducting Retrospective Analyses

The purpose of the final phase depends on the theoretical intent of the design experiment, which is most often driven by the research question set by the researcher and involves an analysis of the entire set of data collected over all three phases of the
SDE. The primary aim remains the construction and revision of the local instruction theory.

This phase is different from the macrocycle of analysis discussed in the previous phase because for this the primary focus is to discuss the nature of the design, and the data analysis involves a larger amount of data than in the microcycle, but does not include all of the data.

The analysis in this third phase is more focused toward theory building and answering the study’s research questions and involves the analysis of the entire process from the conception of the design to its implementation and the completion of the macrocycle of analysis. In this study, I conducted a retrospective analysis of the data collected during the entire study and documented all the elements of the SDE. I provide an outline of these three phases along with the purpose of each phase and the data collected in Table 4.3.1.
Table 4.3.1: *Three Phases of the SDE*

<table>
<thead>
<tr>
<th>Phase 1: Preparing the experiment</th>
<th>Phase 2: Experimenting to support learning</th>
<th>Phase 3: Conducting retrospective analysis</th>
</tr>
</thead>
</table>

The object of this phase is to construct a local instruction theory, which includes the nature and description of instructional activities for the intervention designed to support learning, a vision of the classroom culture, the role of the stakeholders involved, and an inferred process of the learning of the students [Gravemeijer and Cobb, 2006].

Gravemeijer and Cobb [Gravemeijer and Cobb, 2006] suggest that a way to construct this local theory is to establish instructional endpoints and starting points.

The purpose of this phase is to extend and improve the local instruction theory and to develop an understanding of how learning occurs, framed within this local theory.

To achieve this, during the implementation of every lesson/activity and after, the researcher/research team analyzes the participation and learning processes of the students. They then make decisions about the local instruction theory, revising it to address the specified aspects of the design and achieve the goals of all the participants involved.

This process of implementing, analyzing and revising, can be seen as microcycles of design and analysis.

The purpose of the final phase depends on the theoretical intent of the design experiment, which is most often driven by the research question set by the researcher and involves the analysis of the entire set of data collected over all three phases of the SDE. The primary aim remains the construction and revision of the local instruction theory.
<table>
<thead>
<tr>
<th>Processes: Data collection and construction of local instruction theory (design of equitable science classroom)</th>
<th>Processes: Data collection and revision of local construction theory</th>
<th>Processes: Data analysis and final revised construction of local instruction theory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data sources: Literature review, Teacher interview, Teacher Artifacts, Field Journal</td>
<td>Data sources: Teacher debriefing, Field journal, Classroom observation, Teacher and student artifacts, Student interviews</td>
<td>Data sources: All primary and secondary sources from Phases 1 and 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Methods of analysis: Thematic analysis</td>
</tr>
</tbody>
</table>

### 4.4 Goals and Elements of the SDE

The primary goal of the SDE was to transform instruction to be more equitable by enacting practices that center students’ lives and experience. I had a preliminary goal for the design of the intervention: to understand how equitable science lessons can be developed and enacted in public schools and their science classrooms. This goal was refined and reinforced after my conversations with the teacher, where he expressed similar goals during the collaborative design and implementation of the lessons. In reviewing the theoretical framework and other instructional models of equity, we noted that respecting students’ experience and knowledge through instruction was an essential component to achieving equity in instruction. The teacher also regularly expressed his philosophy of teaching as valuing students’ lives and supporting student success in equitable and expansive ways. This then became the central focus of our design. Our guiding question as we collaboratively designed and reflected on the lessons was “How do we value, integrate, and expand students’ cultural repertoires
of practice to teach science/chemistry in equitable ways?"

This question was translated into an instructional model that we could utilize to guide the design of future lessons and analyze past lessons for student-centered practices. This model was informed by literature review and both teacher and researcher experience. In order to support the teacher in this process, I created spaces of reflection as part of the SDE where we explored theoretical concepts together and attempted to translate them into practice as we designed the lesson. Therefore, the goal of the SDE was twofold: (1) to develop instructional practices that value, integrate, and expand students’ cultural repertoires of practice and (2) to facilitate opportunities for the teacher to reflect on and transform instructional practice in ways that center student lives and experience. In the following sections, I detail the various parts of the design experiment we created to accomplish the goals.

4.4.1 Major Design Elements

The SDE has two major purposes and can therefore be seen as two separate activities, although in the real-world context these activity systems are interrelated and interdependent. As stated earlier, the SDE is constructed of two parts: one to support teacher learning and the other to support student learning. I have provided an illustration to represent the separate activities of supporting the teacher and the students in the Appendices C and D to provide a list of resources that had an impact on the learning of the teacher and the students.

1. Experiment to support teacher

   (a) Activity system: collaborative design
(b) Informed by strategies used to support development and transformation of teacher practice toward equity

2. Experiment to support students

(a) Activity system: equitable chemistry instruction

(b) Informed by strategies of culture-based models of equitable instruction in science

We created a design experiment to explore and engage collaboratively with the teacher to examine how equitable instruction can be enacted in the science classroom. This SDE consisted of three main elements to facilitate the transformation of instruction: (1) teacher support sessions, (2) chemistry lessons/units, and (3) a model for student-centered equitable science instruction (SCESI). All three elements play a role to support both teacher’s and students’ learning in the SDE.

The teacher support sessions were designed to facilitate opportunities of joint learning and reflection on what it means to design and teach equitably from a CHAT perspective. The sessions were spaces for the teacher and researcher to learn and engage in the theory informing this work, reflect on perspectives of equity, and reflect and transform instructional practice. These sessions involved reading theory and case studies, reflection, debriefing, and analysis.

To design the lesson, we chose two units from the state standardized chemistry curriculum to iteratively create lessons that would lead to equitable or expansive outcomes. The first unit was a focus on scientific and engineering practices and the second unit dealt with nuclear energy. We developed a model to guide our reflection on instruction and our design and practice. In turn, the implementation of the lesson and
post-lesson reflections helped refine the model. We developed this model from our own reflection and discussions during the design experiment. I formally operationalized it utilizing research literature to provide more robust and targeted guidelines for reflection on equitable practice and transformation of practice.

4.4.2 Teacher Support Sessions

I developed the teacher support sessions to facilitate opportunities for the teacher to learn and reflect on perspectives of equity and learning in science. This was essential to the process of designing and developing equitable instruction because I view teachers from a non-deficit perspective as “transformative intellect” [Fowler-Amato and Warrington, 2017, Giroux, 1985] who engage in critical reflection on theory and practice. I shared research studies and literature on equitable science instruction and learning theories with the teacher to help develop the local instructional theory and include the teacher’s perspective of learning and equity. These sessions also served as the space for us to design the lessons together and iteratively reflect on them after their implementation to learn from and revise the instructional plan and model.

My decision for ways and means of supporting the teacher was derived from my conversations with the teacher and my reflections on our practice. The teacher support plan also went through iterative processes of design, implementation, reflection, analysis, and revision. The topics were chosen based on what the teacher shared during our conversation and needed support on. I also chose methods of support, such as written reflection, based on the suitability of the teacher’s schedule and learning style, which, for instance, involved a preference to write first and then reflect orally together. With initial grounding in literature on teacher education for equity and
on beginning science teachers, these sessions were structured as follows: The teacher read a shortened article on the theories used in this study (expansive learning, sociocultural perspectives of learning, and equity and social justice) and reflected on these readings through written reflections followed by a discussion. The topics were often decided weekly based on the previous week’s reflection. For example, the teacher was unaware or initially did not share a learning perspective that included culture in the process; therefore, I began by introducing the teacher to literature on sociocultural perspectives on science education and then offered CHAT as one of the sociocultural perspectives on learning. I also shared literature on definitions of equity to draw out the teacher’s own views of equity and critiques of other views of equity. This was essential to including the teacher’s voice in the design and to building shared understandings of the theory and practice we wanted to implement. Due to the time constraints of the hectic schedule of the teacher, I led the analysis of our conversation and consequent choices of reading and reflection. The readings provided for the teacher were informational documents that consisted only 1-2 pages each. I constructed these short documents from original theoretical journal papers to help the teacher focus on the topic of discussion in the short time period he had. I also included any resource the teacher shared during our debriefings. For example, the teacher shared the online informational website Miseducation, which presents data on racial disparities in learning opportunities and disciplinary practices in visual forms [Groeger et al., 2018] and served as a spark to discuss how schooling practices such as tracking are inequitable.

These sessions also included reflection and discussion of the day’s instruction and future instructional planning. The debriefings’ reflective questions were composed of some standard questions that were repeated (such as “What went well today and
why?”) and questions prompted by my observation of classroom instruction (such as “What do you look for or assess during small-group work?”) to help understand his practice. These sessions were also planned and timed according to the teacher’s availability and schedule. We met online or after class according to the schedule we created initially: two times per week during the entire semester (August to December) on Tuesdays and Thursdays. We did not always get the opportunity to follow the schedule strictly due to unexpected interruptions or the need to focus on our school priorities. Our meetings each lasted an hour and we met only during weeks that focused on the lessons we designed and not during other times, such as when preparing for the unit tests or standardized exams. I also sometimes visited the classroom without collecting data as the teacher encouraged me to build relationships with the students. I provide the list of topics and their associated readings and reflection prompts in the table below. All the readings and written reflections shared are in the Appendix O.

4.4.3 Student-Centered Equitable Science Instructional Model (SCESI)

In my review of literature on equitable science instruction, I noted that a common theme is the emphasis on students’ experience and practices. This shift from authoritative teacher-centered models to equitable student-centered models is also reflected in most standardized teaching standards such as the Standards for Professional Learning (National Educators Association, NEA, 2011) and standardized science curriculum such as the Next Generation Science Standards [NGSS Lead States, 2013]. In culturally relevant, responsive, or sustaining models, getting to know your students and leveraging their practices and experience to achieve success in the science
classroom is an essential first step. Lee and Buxton [Lee and Buxton, 2010] argue that equitable learning opportunities only occur when we teach science in a way that “explicitly values and respects the experience that all students bring” (p. 5). This became the starting point for the development of our model. This model is composed of three dimensions that address types of practice (and perspectives) that teachers could utilize to begin instruction from student lives: (1) value, (2) incorporate, and (3) expand students’ repertoires of practice. See Figure 4.4.1 for an illustration of the instructional model.
• Value students’ repertoire of practice. The objective of the value dimension is to respect the students’ experience: the practices, understandings, skills, and knowledge they have developed during their lifetime. Doing this involves get-
ting to know your students in authentic ways in order to learn about who they are and what they value. Building authentic relationships is the essential first step in valuing students and understanding their practices from a non-deficit perspective. It is essential at this stage to check our privileges and biases and challenge our deficit views. We utilized the word “value” because it was one of the words the teacher used to describe how he views students. The teacher’s conversation revealed that his priorities of trust, respect, and care were essential to building authentic student-teacher relationships. These authentic relationships serve as springboards to understand what cultural practices students bring to the classroom and how can they be leveraged to engage them in relevant and meaningful goal-oriented activities that support successful science learning.

In this study, the teacher used introductory questionnaires to get to know his students and their goals and motivations. Other non-deficit ways to get to know students include creating learning activities that encourage drawing self-portraits to identify funds of knowledge students bring to the classroom [González et al., 2005].

Gutiérrez and Vossoughi [Gutiérrez and Vossoughi, 2010] propose a method of cognitive ethnography to observe students in non-deficit ways: not merely listening or observing what they do but paying careful attention how they participated in a specific activity designed over time and space. This shifts our focus from a deficit view where we identify what the students lack in meeting content goals and instead emphasizes practices in which the students have historically engaged that can be leveraged and transformed to engagement in meaningful learning.
I propose a set of guiding questions along with the conceptualization of each domain to help begin the process of designing student-centered lessons. In order to organize learning that values students we can ask - What are the practices students need and use today, and how are they used? What are the students’ histories of participation in these practices?

- **Incorporate students’ repertoire of practice.** In this dimension, centering students’ experience and including students’ knowledge, skills, and strengths as starting points of science instruction is the main focus. Despite building strong relationships or getting to know the students and their practices in a classroom, these relationships are often seen as separate from the content or external to the classroom instructional practice. This dimension is therefore extremely important to designing equitable science instruction because it requires educators to think deeply and deliberately about how our science instruction serves our students, and not the other way around. The relationships built and practices listed from the above dimension are now employed to create learning opportunities to engage students in meaningful participation and learning.

In this study, we created lessons to reflect the students’ culture and identity, see the ways in which science is used to solve problems within a community or in their own lives, and think deeply about how science can continue to serve their community while also challenging the ways in which science had been inequitable for communities of color. For example, the second lesson we created focused on how nuclear energy is converted and used to provide electrical energy to students’ homes and the local community. We also asked the students to consider the economic and environmental impact of the local nuclear energy
power plant on their community. We organized the activity so that the students worked in groups to construct and present knowledge in “teams” because we learned from the results of our student questionnaire that most of the students participated in team sports. We also encouraged the students to take responsible roles in supporting their teams to achieve the goal because from the student questionnaire, administered at the start of the semester, we knew that a lot of the students in this class had responsibilities such as working a job or taking care of siblings.

Another important aspect to consider when bringing in students’ practices and knowledge is the “danger of colonizing” student practices for school and district purposes and not ones that students value [Gutierrez et al., 2007]. This means that when we observe and utilize student practices in the classroom, we do so to engage students in science in ways that are meaningful and relevant to them and their success rather than just as a way to meet milestones such as the required scores on standardized assessments created by the school or district, which continue to perpetuate oppressive and marginalizing schooling practices. This requires educators to reframe their orientation away from content and grades to meaningful success of the students.

Guiding questions for this domain include: How can science help students achieve goals that are relevant and meaningful to their lives? How can science help students to achieve goals that are essential for them to succeed in a world where power and the agency to act in unequally distributed? What learning opportunities can be created where the students’ practices and experience are incorporated to serve their own purposes rather than those of the school?
• *Expand students’ repertoire of practice.* The purpose of this dimension is to “expand” a student’s toolkit of practices beyond memorization and understanding of content (especially for testing and evaluation purposes) to include tools they can deploy to succeed in this world on their own terms. This dimension is derived from the conceptualization of expansive learning. The object of expansive learning is to build upon the students’ toolkits of practices in order to develop critical understandings of texts, ideas, and histories. Expansive learning, as discussed in Chapter 3, is learning that expands one’s possibilities of acting in the world, thereby increasing agency. A critical understanding illuminates the cultures of power that exist and influence students’ lives and learning in different ways. They learn content and develop practices in critical ways that help them achieve their own goals and motivations. In a world that is inequitable, especially toward students of color, it is essential that instruction is geared toward providing them resources to engage with and challenge systems of inequities while simultaneously providing tools to build meaningful lives. Science instruction therefore becomes a source of expansion where they construct and understand scientific knowledge and develop scientific practices in ways that are relevant to them and that can be used to solve problems in the lives of their families or communities and challenge existing systems of inequity.

In our study, we provided text and created opportunities for reflection that encouraged students to think about issues such as the underrepresentation of people of color in college and professional careers related to science. The goal of the lesson was to use this underrepresentation as the starting point to think about how identity and culture play a role in the scientific community and how structures exist that are inequitable toward communities of color. The nuclear
energy power plant lesson was created to offer opportunities to students to not only engage in practices they had already developed, such as teamwork, but also to expand their own practices, ranging from simple tasks such as how to create an argument and communicate scientific information to complex tasks such as advocacy or environmental activism related to the effects of harnessing nuclear energy, thus offering new ways to interact with world.

Guiding questions for this dimension include: Do the activities designed create opportunities for critical thinking? Does the lesson encourage students to think deeply and critically about the impact of science on their own lives and the world? Does the instruction provide new scientific tools to increase students’ agency (possibility to act in the world)? Does the instruction provide new scientific tools to challenge systems of power?

4.4.4 Chemistry Units

For this study, we designed two chemistry lessons to utilize student-centered instructional practices. We had chosen two units from the list of chemistry units that were prescribed to the students for the semester (See Appendix E for detailed list of the units taught during the semester). The teacher considered these two units non-essential because they did not make up a large portion of their testing and preparation for the next chemistry course in the sequence of classes required by graduating secondary students. This was important because the teacher needed to maintain a schedule that ensured completion of all units for the semester, and I respected that because the teacher was still accountable to his department and the school to complete the required list of units and support students in successfully completing their standardized assessments.
The units were in accordance with the Chemistry I state standards because it was a priority for the teacher to meet the required content standards. The two units were (1) science and engineering practices and (2) nuclear chemistry (as part of the atomic structure and nuclear processes unit). We implemented the same lesson instruction in both the honors and college preparatory (CP) sections. However, the lessons were adapted differently during the implementation based on the reflection and analysis of the implementation in each section. I provide a brief description of the lessons and have shared the formal lesson plan (framed within the activity triangle) in the Appendix.

4.4.4.1 Lesson 1: Underrepresentation in the Scientific Community and Science and Engineering Practice

This was the first lesson we co-planned. I also supported part of his instructional implementation by helping to teach parts of this lesson. The teacher led the lesson and discussions. I supported group work and any additional questions students had. In the past, the teacher had shared a list of the science and engineering practices with the students and engaged them in one or two of the practices listed, such as analyzing and interpreting data and constructing arguments with supporting evidence using a fake data set. The instructional plan included providing students with graphing tools and a worksheet for students to fill in their answers.

For this study, we agreed to follow a similar pattern of instruction but focus on what students need and what is relevant to them. We utilized a data set from an online resource and adapted a portion of the lesson plan associated with the resource. The online source was from the Underrepresentation Curriculum Project by the Underrepresentation Curriculum Group [The Underrepresentation Curriculum Group,
2019]. The data set and the original lesson plans are in the Appendix, along with the lesson we designed.

The students were provided with real data in a table from a report on the representation of various racial and ethnic groups in science in terms of number of degrees (bachelor’s, master’s, and doctoral) awarded to different cultural groups. The students were asked to create a graph to represent the data and then analyze it. They were encouraged to interpret the results and offer plausible, evidence-based reasons to support their interpretations. They were asked what the data representation showed, what this could mean, and how they felt when they saw the data and its representation. The teacher utilized an online technological platform called Padlet for students to share their anonymous interpretations. This was used to engage students in a classroom discussion and address their concerns and stereotypes related to race and science.

4.4.4.2 Lesson 2: Nuclear Power Plant Committee Hearing

The second lesson we co-planned involved presenting nuclear energy to the students in a relevant way. We utilized a community issue as the starting point of the lesson. The community in which the students lived, including me and the teacher, received electricity from the local nuclear power plant. We used this as the premise for a project-based lesson. The idea to use a community-based problem as the starting point for the lesson was sparked by the teacher during our first interview when he mentioned that he had wanted to explore issues of water in Flint, Michigan, from a chemistry perspective because some of his students from previous classes had mentioned it and he thought it was a current, relevant, and important issue to understand.
For the lesson on nuclear energy, we created a situation that mimicked real events in which the US Nuclear Regulatory Commission (NRC) was hosting a town hall meeting to discuss the renewal of the license of the local nuclear power plant. The students were randomly assigned groups, where each group represented a particular professional career that had important roles related to the nuclear power plant. These roles included nuclear scientist, nuclear technician, science policy advisor, social activist, water chemist, and environmental health and safety officer. This instructional plan and the formation of the groups followed the pattern of a jigsaw activity often used in classrooms where each group develops expertise in different areas and shares their expertise with the other groups so the whole class is aware of the entire content. The teacher first shared an initial plan of instruction along with his goals and motivations. We then utilized that plan as the starting point and revised the plan to focus on integrating and expanding students’ practices. In the initial plan (in the Appendix), the teacher wanted to explore the ethics of a nuclear power plant while also providing space for the students to learn the necessary content on nuclear energy. He also included information related to local community knowledge, such as the origins of the name of the lake constructed to support the power plant and how the lake was constructed. His initial plan to explore the positive and negative impact of nuclear energy consisted of creating two roles: community member and nuclear engineer. Using informational sheets on how a nuclear plant functions and how the lake was constructed, the students would complete worksheets from both perspectives to help them understand the ethical implications. From here we revised the lesson to increase the number of roles in order to offer more diverse perspectives, build comprehensive roles to understand what professions exist that utilize science or chemistry to solve problems, offer students space to conduct their own research and construct their own knowledge, and present their knowledge and opinions in a manner that is
reflective of the real world, such as making an argument against the renewal of the
license using evidence-based arguments and presenting these arguments in a public
space to inform the community.

In this lesson, the students were first presented with the issue and then the different
professional roles through which they would present their arguments. Each role was
constructed to include a position on the nuclear power plant (for or against), details
about what the role comprises (such as what nuclear technicians or social activists
do), informational sheets that contained content related to their roles (such as defining
types of nuclear processes for nuclear scientists and nuclear accidents that have had
a negative impact on cities for social activists), graphic organizers to support their
knowledge construction, and template slides. This information was put into Google
Drive folders and shared with the students. The students worked in groups to first
cull relevant information into the graphic organizers to support their position for or
against the renewal of the license. They then were encouraged to use the graphic
organizers as ways to organize the information they had learned and construct an
argument to present to the audience. The final goal of the lesson was to present a
valid argument to the NRC committee, which the teacher and I enacted. Similar to
the previous lesson, the teacher led the implementation of the lesson, including the
introduction to the activity and the whole-classroom discussions. I helped the teacher
during small-group work by working with different groups to support their learning
and creating the presentations. We jointly evaluated the student presentations and
provided feedback. In contrast to the previous lesson, students had to work in teams to
develop expertise in different areas, present their information in a new and unfamiliar
manner (present to a larger audience using PowerPoint slides), and include their
own opinions supported by evidence that was a critical evaluation of the texts they
were provided with. The lesson plan along with the material created by the teacher, researcher, and students are in the Appendix.

4.5 Research Methods

4.5.1 Participants and Site Selection

The participants for this study were the science teacher Andres (a pseudonym) and the students (who volunteered to participate) of a High School Chemistry I (Introduction to Chemistry) class.

The members of my committee recommended this teacher due to his reputation of working with emergent bilingual students successfully and due to my interest in working with students from non-dominant communities. I was introduced to Andres through email by one of my committee members. He agreed to participate in my study because of his interest in expanding his teaching practice in more equitable ways.

At the time of the study, Andres was enrolled in an online master’s program in literacy. Andres was a 24-year-old bilingual (Spanish and English) male teacher and had been teaching in this high school for three years. He identifies as Latino-Asian. For this study, I observed three sections he taught. This school followed the tracking system; therefore, two of the sections he taught were Chemistry I Honors and the third was a Chemistry I college preparatory (CP) course.

The students in the classroom consisted of 34 girls and 29 boys between the ages of 13-15 years old. The racial and ethnic identities of the students in the three sections
were: 20 Hispanic students, 23 White students, 17 Black students, and 2 students who identified as Other. Of these students, 19 students volunteered to participate: 10 female and 9 male students.

4.5.2 School and Community Context

Cases are situational in nature; therefore, contexts are essential to the case study methodology [Lincoln and Guba, 2000] and the SDE [Roth et al., 2009]. The case under focus was a complex system and embedded within historical, cultural, social, economic, political, ethical, and even physical contexts [Stake, 2005] that reveals the various relationships between the components of the case and provides significant insight. The school was located in a district in the southeastern United States that hosted a prominent Hispanic community segregated from the rest of the majority White communities in the district, a situation that is often seen in rural and suburban towns with a large influx of Latinx families [Lichter et al., 2015]. The racial profile of the area, as measured in the 2010 census (US Census Bureau, 2010) was 60.6% White, 18.1% African American, 0.51% Native American, 1.2% Asian, 0.007% Pacific Islander, 16.9% from other races, and 2.7% from two or more races. Hispanic or Latinx people of any race were 25.4% of the population. People of Mexican ancestry made the largest portion of the Hispanic or Latinx population at 14.1%. The racial and gender composition of the school was 32% Latinx, 31% Black, 33% White, and 4% Other races and 51% female and 49% male. Compared to this, the state’s student demographic is 9% Latinx, 34% Black, 52% White, and 4% Other races.

The science curriculum is guided by state standards. The state does not follow a national curriculum but has topics and framing of language (in the form of science and engineering practices) that are similar to national curriculums such as the Next
4.5.3 Data Sources

My primary sources of data include semi-structured teacher interviews, audio-recordings and field notes of reflection and debriefing sessions, and video recording and field notes of classroom observations. The secondary sources of data include student interviews, and teacher and student documents related to classroom instruction. Table 4.5.1 provides a brief overview of sources of data collected and their purpose. I have organized the sources using the three phases of the research design and explain each source in detail.

Table 4.5.1: Outline and description of the various sources of data and purpose

<table>
<thead>
<tr>
<th>Phase</th>
<th>Weeks/Timeline</th>
<th>Purpose</th>
<th>Data Sources</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>August 2018</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Collect baseline data: teacher planning, practice and perspectives</td>
<td>• Teacher life history interview (audio recording)</td>
</tr>
<tr>
<td></td>
<td>• Design teacher support material from teacher experience and skills to help build equitable intervention/lesson</td>
<td>• Informal planning conversations (audio recording and emails)</td>
</tr>
<tr>
<td></td>
<td>• Iteratively develop with teacher equitable intervention/lesson for students</td>
<td>• Teacher support materials created by researcher</td>
</tr>
<tr>
<td></td>
<td>• Teacher life history interview (audio recording)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Informal planning conversations (audio recording and emails)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Teacher support materials created by researcher</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reflections by teachers (written)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Teacher reflection (audio recording)</td>
<td></td>
</tr>
<tr>
<td>Phase 2</td>
<td>August-October 2018</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>---------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Implement intervention/lesson for students</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Iteratively reflect on and revise intervention/lesson</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
**Interviews.** I utilized the semi-structured interview form for my study. This type of interview is often associated with qualitative interviews [Warren, 2002] because it is more flexible in terms of the questions asked and the answers expected and is not rigid like the structured interview often seen in surveys. This flexibility allows for an understanding that emerges from it. [Brinkmann and Kvale, 2015] define it as “an interview with the purpose of obtaining descriptions of the life world of the interviewee in order to interpret the meaning of the described phenomena” (p. 6). This type of interview does contain some structure. I interviewed the participating teacher to learn about his background (both his teaching and learning experience in science) in order to begin the conversation about his goals and motivations for constructing this curriculum and to identify and discuss his views on equity in the classroom. I also interviewed the teacher again toward the end of the design experiment to capture and in-
corporate his interpretations of the design and to serve as a member-checking process of my own interpretations. I interviewed the students at the end of the SDE to understand their experiences of the lessons to inform the model and future designs of equitable instruction. The interview protocol for the teacher and the students is in the Appendix.

• **Participant observation of classroom.** *Participant observation* involves the two main processes of participation and production of written observations. This process is aimed at the close observation and study of people and practices as they go about their everyday routines. This involves entering into a setting to build relationships and participating in these activities to continue developing these relationships and making observations about the practices [Emerson et al., 2011]. With advances in technology, these observations are not limited to researcher-written notes but can also incorporate video recordings of the same observations that corroborate and extend the data collected and analysis. As a participant observer, I aimed began to build relationships with the students and the teacher by supporting instruction, in a role similar to a teacher’s aide, in order to be sensitive to their needs for the study and to understand where they come from in terms of their motivations, goals, and dreams.

I made reflective notes of my observations during the class and used a video camera to record the classroom instruction. As a participant observer, I often helped the teacher in implementing the lesson by adding to the conversation or working with the students in small groups to address their doubts. In instances where I could not write immediate notes, I made post-reflective notes while watching the video after the classroom observations. For a complete list of
the number of sessions and the dates of these sessions, Table 4.5.3 provides a document of the data collected and the chronology of the collection.

- **Teacher Debriefing and Reflection Sessions.** Reflection on teaching practice is an essential component of teacher learning and development [Schön, 1983]. Self-reflection on teacher practice, along with observation and feedback mechanisms are now an essential aspect of most teacher learning programs and evaluations. These debriefing sessions with the teacher provided space for two purposes: (1) to collaboratively plan, reflect on, and revise the lessons or interventions for the students and (2) to facilitate opportunities of reflection for the teacher on the meaning and practice of equity. We met once every week during the implementation of the study (August to December 2018); some sessions were conducted online using conference software such as Zoom and the rest were conducted during the teacher’s planning period in the classroom after the lessons were implemented. These sessions were a mixture of post-lesson debriefing and reflections on readings related to equity. See Table 4.5.2 for sample reflective questions.
Table 4.5.2: Reflection and debriefing prompts for the teacher

<table>
<thead>
<tr>
<th>Reflection:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Quick recap of the week (refer to weekly lesson plan)</td>
</tr>
<tr>
<td>2. Rationale behind the decisions you made during planning and implementation</td>
</tr>
<tr>
<td>3. One of your successes during the week (What worked?)</td>
</tr>
<tr>
<td>4. One of your challenges during the week (What did not work?)</td>
</tr>
<tr>
<td>5. One thing you learned from the week’s success or challenge</td>
</tr>
<tr>
<td>6. One idea from today you would like to explore further</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activity: What does equity mean to you? (Reflection on readings and sample)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What stood out to you about the authors’ definitions of equity? How might this contrast with yours and other definitions?</td>
</tr>
<tr>
<td>2. How do the cases reveal why it is important for science learning to relate to experiences that students have beyond the immediate learning environment?</td>
</tr>
</tbody>
</table>

- **Documents.** The main purpose of collecting documents is to support the analysis of the other primary sources of data, such as interviews and observation of teaching practice, and contribute to the construction of the findings and interpretations. These documents are classroom related and act as data sources to refer to what participants mention or discuss in the dialogues and interviews. I collected several different types of documents related to the design and the
implementation of the instructional activities.

These included teacher lesson plans, supporting material such as PowerPoint presentations, student surveys and worksheets, student homework, and student classwork, which includes any notes, projects, presentations, laboratory observations, tests, and quizzes. The students filled in questionnaires administered both on paper and online platforms such as Google Forms that served to identify their interests and routine everyday practices to help trace the repertoires of practice they have developed. It also served to capture their feedback on the design.

Table 4.5.3: Audit log of data collected and process of analysis, arranged chronologically

<table>
<thead>
<tr>
<th>Date</th>
<th>Data</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug 9</td>
<td>Teacher interview and planning</td>
<td>Transcribe, open coding + Summarize key concepts and major events discussed</td>
</tr>
<tr>
<td></td>
<td>Audio recording (TI.1)</td>
<td></td>
</tr>
<tr>
<td>Aug 17</td>
<td>Teacher interview and planning</td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td></td>
<td>Audio recording (TI.2)</td>
<td></td>
</tr>
<tr>
<td>Aug 28</td>
<td>Audio recording of teacher Reflection (TR.1)</td>
<td>Transcribe, open coding Summarize key concepts and major events discussed</td>
</tr>
<tr>
<td>Aug 30</td>
<td>Audio recording of teacher Reflection (TR.2)</td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td>Date</td>
<td>Event Description</td>
<td>Coding Method</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------------------------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Aug</td>
<td>Written reflection <em>WR.1</em> (Teacher of the year application)</td>
<td>Open coding</td>
</tr>
<tr>
<td></td>
<td>Student surveys (<em>SS1</em>)</td>
<td>Open coding</td>
</tr>
<tr>
<td></td>
<td>Underrepresentation and scientific practice lesson plan (<em>LP1</em>)</td>
<td>Open coding</td>
</tr>
<tr>
<td></td>
<td>Supporting materials for <em>LP1</em> and classroom documents (<em>CD1</em>)</td>
<td>Open coding</td>
</tr>
<tr>
<td></td>
<td>Student work/responses for <em>LP1</em> (<em>CD2</em>)</td>
<td>Open coding</td>
</tr>
<tr>
<td></td>
<td>Student exit tickets (<em>CD3</em>)</td>
<td>Open coding</td>
</tr>
<tr>
<td>Sep 7</td>
<td><em>TR.3</em></td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td>Sep 11</td>
<td><em>TR.4</em></td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td>Sep 13</td>
<td><em>TR.5</em></td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td>Sep 20</td>
<td>Classroom Observation (<em>CO.1</em>), <em>TR.6</em></td>
<td>Summarize, identify key moments</td>
</tr>
<tr>
<td>Sep 21</td>
<td><em>CO.2</em></td>
<td>Summarize, identify key moments</td>
</tr>
<tr>
<td>Date</td>
<td>Code</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>--------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>Sep 26</td>
<td>TR.7</td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td>Sep 27</td>
<td>TR.8</td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student interest survey</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(SS2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Open coding</td>
</tr>
<tr>
<td>Oct</td>
<td></td>
<td>Nuclear chemistry LP2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Open coding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student work for LP2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Open coding</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Student survey for LP2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(SS3)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Open coding</td>
</tr>
<tr>
<td>Oct 2</td>
<td>CO.3, TR.9</td>
<td>Summarize, identify key moments to support</td>
</tr>
<tr>
<td>Oct 3</td>
<td>CO.4</td>
<td>Summarize, identify key moments</td>
</tr>
<tr>
<td>Oct 4</td>
<td>CO.5</td>
<td>Summarize, identify key moments</td>
</tr>
<tr>
<td>Oct 5</td>
<td>CO.6</td>
<td>Summarize, identify key moments</td>
</tr>
<tr>
<td>Oct 8</td>
<td>CO.7, TR.10</td>
<td>Summarize, identify key moments</td>
</tr>
<tr>
<td>Oct 11</td>
<td>TR.11</td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td></td>
<td>WR.3</td>
<td>Open coding</td>
</tr>
<tr>
<td>Oct 18</td>
<td>TR.9</td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td></td>
<td>WR.4</td>
<td>Open coding</td>
</tr>
<tr>
<td>Oct 25</td>
<td>TR.12</td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td>Date</td>
<td>Description</td>
<td>Coding Method</td>
</tr>
<tr>
<td>------------</td>
<td>--------------------------------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Oct 29</td>
<td>W.R.3</td>
<td>Open coding</td>
</tr>
<tr>
<td>Nov 6</td>
<td>TR.13</td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td>Nov 19</td>
<td>TR.14</td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td>Nov 29</td>
<td>TR.15</td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td>Dec 11</td>
<td>Classroom visit</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(no data collection)</td>
<td></td>
</tr>
<tr>
<td>Dec 13</td>
<td>Classroom visit</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(no data collection)</td>
<td></td>
</tr>
<tr>
<td>Dec 17</td>
<td>Student Interviews: First block</td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td></td>
<td>SI.1</td>
<td></td>
</tr>
<tr>
<td>Dec 18</td>
<td>SI.2</td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td>Dec 19</td>
<td>SI.3</td>
<td>Transcribe, open coding</td>
</tr>
<tr>
<td>Jan 31, 2019</td>
<td>Final Teacher Interview (TI.3)</td>
<td>Transcribe, open coding</td>
</tr>
</tbody>
</table>

### 4.5.4 Data Collection

I collected and organized my data in three phases (as seen in Table 4.5.1). Phase 1 was the introductory phase where the primary focus of data collection was to build a relationship with the teacher and better understand the teacher and his motivations. During this phase we also began planning for possible lesson interven-
tions for students. From the teacher interview and his discussion of equity, I began to plan for readings and related reflection prompts that could facilitate the teacher’s reflection on the meaning and practice of equity.

During Phase 2, the teacher and I collaboratively planned and implemented the lessons. We chose to design lessons based on standards related to two units: introduction to scientific practices (as part of Unit 1 on scientific foundations) and nuclear chemistry (as part of Unit 3 on atomic structure). During this phase we continued to meet for reflection once a week and have debriefing after the lesson. I also visited the classroom two times a week to observe and record the teacher. The teacher initially shared reflections orally during our conversations and eventually, due to time constraints, shared written reflections. I would then ask follow-up questions during our reflection sessions to clarify and expand on his written reflections. As we implemented the lessons and reflected, I engaged in reflection and analysis of each classroom observation and reflection, noting down my initial thoughts and emergent themes in analytic memos [Saldaña, 2013]. Each session’s reading and reflection prompts were derived from the previous discussion and analysis of the teacher’s reflection and lesson plans. For example, I introduced sociocultural perspectives of learning to the teacher because during the initial interview he had expressed views that had reflected a view of science content as being “culture-free.”

In the final phase, Phase 3, I interviewed the teacher and the students, which served as the member-checking process. The teacher interview and reflection are the primary sources of data during this phase. The purpose was to document changes and tensions in the teacher’s practices and discourse and to serve again as a final space of reflection on meaning and practice. The student interviews were supporting
or secondary data, the purpose of which was to evaluate the design of the two lessons created in this SDE. At the conclusion of the study, I conducted retrospective analysis of data [Gravemeijer and Cobb, 2006]. I describe the process of data analysis in the next section.

### 4.5.5 Data Analysis

The purpose of this study was to document, examine and support construction of the design of the equitable intervention in the chemistry classroom. My research questions for this study were:

1. How did a beginning science teacher of color learn and develop student-centered equitable instructional practices within the space of an SDE?

2. What were the tensions that emerged as the beginning science teacher of color developed equitable instructional practice in the SDE? How did the teacher negotiate these tensions?

I utilized thematic analysis to inductively analyze the raw data by repeatedly viewing, listening to, and reading the data with increasing depth to identify the significant moments. I utilized a paid software service to transcribe the recorded data, such as interviews and reflection sessions. I converted the video to audio to transcribe them. I inductively coded [Miles et al., 1994] (Miles & Huberman, 1994) the textual data through multiple readings and interpretations, recording the emerging codes and categories in analytic memos [Saldaña, 2013].
4.5.6 Data Corpus, Data Set, and Unit of Analysis

During the course of this study I collected several forms of data from the teacher and the students forming a large data corpus, as indicated in the previous sections and tables. The data corpus consists of all the data that was collected for this research study, which includes the primary and secondary sources of data from the students and the teacher participating in this study. However, I used only a fraction of this data corpus for my analysis, which forms my data set. I chose my data set based on two criteria derived from my research questions: (1) focus on data items (individual pieces of data collected) related to teacher learning and practice such as teacher interviews and video recordings of classroom instruction and (2) focus on instructional practice and tensions encountered.

To answer my research questions, my main unit of analysis was the learning and practice of the teacher, any shifts in this learning and practice, and tensions and contradictions the teacher encountered in his learning and practice. Based on this I noted and examined the various practices and discourse of the teacher in relation to his view on equity and teaching, focusing on changes in practice and discourse, new understandings and tensions or challenges that arose.

In order to focus my data analysis and define my data set, I first cataloged the various sources of data chronologically and by type (see table above for audit trail). The data was separated into text and video/audio. I then logged the various video and audio recordings by watching or listening to them to compose an overview of the recording and document key moments that were relevant to the unit of analysis.
4.5.7 Thematic Analysis

To answer the research questions, I utilized thematic analysis [Boyatzis, 1998, Braun and Clarke, 2006, Saldaña, 2013]. Thematic analysis is a process that reveals and discovers themes, which are identified by researchers from the data, contributing to the description of the phenomena of study [Daly et al., 1997]. The goal of this process is to discern patterns in the data to address a research question. Thematic analysis not only interprets data but also helps to organize and describe the data collected [Braun and Clarke, 2006].

A theme is an outcome of the process of coding data [Saldaña, 2013] that describes and organizes the observations and interprets them [Boyatzis, 1998]. The process involves identifying themes through “careful reading and re-reading of the data” [Rice and Ezzy, 1999, p. 258]. It is a form of pattern recognition and can involve both inductive and deductive approaches [Fereday and Muir-Cochrane, 2006, Boyatzis, 1998]. Braun and Clarke [Braun and Clarke, 2006] provide a six-step guide to conducting thematic analysis: (1) Become familiar with the data, (2) generate initial codes, (3) search for themes, (4) review themes, (5) define themes, and (6) write up. For my study, I utilized several cycles of coding [Saldaña, 2013] to accomplish the six steps. The first two stages of data analysis consisted of pre-coding and open coding, which helped me become familiar with the data (Step 1) and generate initial codes (Step 2).

During pre-coding I identified and demarcated larger sections of the data. For example, in transcripts of the teacher interviews and later debriefing sessions I had marked out sections of the conversation that were related to choosing a chemistry unit for the SDE, distributing participant incentives, or sharing other studies and
lessons that had equitable indicators. This helped to reduce the amount of data that required detailed analysis because I focused on sections of the data sets that were related to my research questions: teacher learning and development of practice along with tensions encountered and negotiated. For example, I focused on our discussions related to the choice of a chemistry unit for the SDE but did not analyze sections that discussed how we would distribute participant incentives or gift cards.

The next stage involved open coding, which is an inductive process. I did not have any pre-set codes but developed codes from reading the data several times. I manually coded my data by printing transcripts of the interviews and reflection sessions and then marking the text with colored pens to label the data with codes and identify potential patterns. The codes identified were not pre-set; however, due to the theoretical orientation, several codes reflected aspects of the theoretical framework. For example, codes such as “expansive learning,” “object,” and “tool” were derived or informed by CHAT.

I also started noting down my initial thoughts and conceptions in analytical memos [Saldaña, 2013]. “Memos are sites of conversations with ourselves about our data” [Clarke, 2005, p. 202]. I reflected on the coding process and the codes, wrote down my thoughts as I observed them, and began to make sense of them and see emergent patterns, categories, and codes. I documented these reflections along with my process of coding in the memos to help me make sense of the data and identify emerging themes. This began the next stage (Step 3: searching for themes).

Several codes were identified, and I collated them together in order to first reexamine and reorganize the codes, where redundant codes or overlapping codes were grouped together or eliminated, thus reducing the number of codes. Due to the open
coding process, several codes that did not align with the research question or did not offer insight with respect to teacher learning of equitable practice were discarded. Next, I returned to the remaining codes I had noted to focus my next stages of analysis on constructing categories and themes [Braun and Clarke, 2006] to begin to look for patterns that would help categorize them and enable meaning making. I initially segregating and grouped codes based on similarities and shared characteristics [Saldaña, 2013] to identify initial categories. For example, I grouped codes such as “standards,” “dates,” “objectives,” “pacing,” “unpredicted interruptions,” “coverage,” “control,” and “intent for student voice” into an initial category I labeled “objectives in instructional Planning.” During this categorization process, the number of salient codes was reduced. Certain codes did not fit into any initial category, and I grouped these together to see if any pattern emerged.

The final stage involved grouping and regrouping codes and categories to identify larger themes that began to address the research questions. This began the next step of reviewing and defining themes (Steps 4 and 5). My research questions revolved around two major concepts: (1) development and enactment of practices and associated learning and (2) tensions and contradictions. Several codes were in contradicting positions, and because the transcripts revealed the tensions the teacher faced, several categories were created that reflected these tensions and contradictions. The categories were finally organized by common features of the practices enacted by the teacher, and this formed the basis of my themes. Within each theme, practices that related to tensions were grouped as a separate category to be discussed in the findings. A summary of each theme along with sample codes are provided in Table 4.5.4.
Table 4.5.4: Summary of themes including guiding question, categories and sample codes

<table>
<thead>
<tr>
<th>Themes</th>
<th>Guiding question for definition of theme</th>
<th>Categories</th>
<th>Sample Codes</th>
</tr>
</thead>
</table>
| Theme 1: Set objectives to center students in instruction | What or whose motives guide instructional decisions or the activity of science teaching in the unit/lesson? | • Learning beyond content  
• Student motivation and interest  
• School motives  
*Tension/Contradiction:*  
• Student interest and pace versus Standardized content and time | Standards, objectives, pacing, pacing to meet student needs, coverage, “what I need to cover,” student excitement, district motives, SLO, learning objectives, critical thinking, beyond memorization |
<table>
<thead>
<tr>
<th>Theme 2: Organize learning for expansive learning outcomes</th>
<th>What forms of learning support or constrain the learning of the students and how are these forms of learning facilitated or organized by the teacher?</th>
</tr>
</thead>
</table>
|                                                            | • Organize learning for student interest and lives  
• Organize learning for student support  
• Organize learning for multimodal communication  
• Assess for learning |
| **Tensions/Contradictions:**                               | Control, student interest, time to explore, notes student excitement, assess students academically, formative assessments, classroom management, assess student work-exit slip, assess time on task, great discussion, structure discussion for voice, structured discussion for safety |
|                                                            | • New forms of learning versus direct instruction for completion of curriculum  
• Assess for learning versus assess for behavior |
<table>
<thead>
<tr>
<th>Theme 3: Build authentic student-teacher relationships</th>
<th>What are the types and the nature of interactions between students and the teacher?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• Role model</td>
</tr>
<tr>
<td></td>
<td>• Connecting to students</td>
</tr>
<tr>
<td></td>
<td>• Attuned to emotional needs</td>
</tr>
<tr>
<td></td>
<td>• Building and leveraging relationships</td>
</tr>
<tr>
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<td>• Care</td>
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<td>• Trust and respect</td>
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**Tensions/Contradictions:**

- Teacher assumptions of “smart” or “well-behaved” students
- Impact on tracking

- Teacher assumptions based on names, teacher recommendation for tracking, frustration, “one of them,” connect to students, humor, gain student trust, tease, “focus on what we have to get done,” talk to students, share personal experiences, sense discomfort, “behavior issues,” good rapport, student emotion
<table>
<thead>
<tr>
<th>Theme 4: Share cultural and historical aspects of scientific knowledge and practice</th>
<th>How is the discipline of science presented by the teacher?</th>
<th>Address racial issues, build racial awareness, nature of science, science as rules, science as prediction, science as problem solving, science as mechanisms, getting science right</th>
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<td>How is the discipline of science presented by the teacher?</td>
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<td>• Universal science</td>
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<td>• Fragmented science</td>
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<td><strong>Tensions/Contradictions:</strong></td>
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<td></td>
<td>• Sociocultural and multicultural perspective of science versus universal scientific knowledge</td>
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<td>Theme 5: Reach out to community of support</td>
<td>Who is part of the community of support of the teacher? What is nature of support received by the teacher from this community?</td>
<td>School support • Department and peer support • Researcher support • Teacher education support</td>
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*Tensions/Contradiction:*

- Lack of parent and community support due to deficit views

Disseminating school expectations, smart lunch/extra academic time, lack of teacher voice in administration, informal check-in with community, self-directed collaboration, compare coverage and pacing

I watched and listened to the videos recorded in the classroom, making physical notes of important events that correlated to the discussions recorded. Video logs help to see patterns of interaction and condense the video data while maintaining the complexity and meaning of the data [Jewitt, 2012] and can be useful when there is a large amount of data because they can reduce the amount of time required to watch and analyze all the videos. My audit trail served as an initial video log. I watched classroom episodes to support the themes and interpretations I had identified in the transcripts of the reflection and debriefing sessions. Since the debriefing sessions were related to the events that occurred in the classroom that day, the video served to
reinforce or refine my initial interpretations.

4.5.8 Methodological Rigor

Webster and Mertova’s [Webster and Mertova, 2007] work in rethinking validity and reliability measures offered new terms of evaluation to guide the researcher to ensure valid and ethical research processes. The main elements of evaluation are access, verisimilitude, honesty, transferability, authenticity, and economy.

Access to the study and its data is an essential component of a valid research study. I maintained an audit trail of the data collected and the progress of the study in Table 4.5.3 to provide access to the data sources and the process of collection and analysis. I labeled every data source and assigned a fixed place to store them in a data collection folder in my password-protected cloud storage and laptop in order to maintain this audit trail. Each data source is labeled with the type of data, like Teacher Interview along with the data collected, like Aug.17 (to indicate the 17th of August). I have used this labeling to note the quotes I used in the findings to illustrate my themes.

Verisimilitude deals with the researchers’ role in maintaining the plausibility of findings and truthfulness in reporting accounts of participants. I made notes about the data collection and analysis processes in my field journal that corresponded to the labelled data to continue to maintain the audit trail, which contributed to the truthfulness of the data. I maintained all the transcripts of the interview to be provided to support any assertion. I also ensured that I was as honest and respectful in my descriptions of the participants as possible and supported the descriptions with a robust literature review (Chapter 2) to maintain verisimilitude.
Honesty in the data is similar to verisimilitude in that it requires maintaining adequate representation of participants’ data. I captured and represented the participants’ voices equitably through repeated cycles of analysis and writing. This is supported by using the quotes of the participants in the findings. I also shared the findings with the teacher participant to ensure adequate representation.

Transferability and authenticity refer to maintaining adequate information that allows the readers to find similarities in their own work in order to make sense of the findings and to convince the readers of the seriousness and honest value of the findings. I provided rich and detailed descriptions of the methodology, methods, data collections, findings, and interpretations. The audit trail and the theory-based analysis and interpretation of the data also contribute to the transferable and authentic nature of a study.

Finally, to maintain economy in a research study is to effectively and economically utilize data and its analysis without compromising on its authenticity and honesty. I define my unit of analysis and focused analysis on those activities that highlight teacher learning for equity. This reduced the analysis process and focused the process on data pertinent to the research question. I focused my analysis on the primary data sources and supported them with secondary sources, thereby reducing the data presented but not losing the integrity of interpretation.
Chapter 5

Findings

5.1 Overview

For this research study, I examined the learning journey of a beginning science teacher of color as he engaged in designing and implementing science instruction that centers students’ lived experience and practices. My focus of analysis was on the teacher’s learning to recognize and reorganize students’ experience and strengths in ways that could lead to expansive science learning outcomes through instructional practice. Based on this, my research questions were:

1. How did a beginning science teacher of color learn and develop student-centered equitable instructional practices within the space of a SDE?

2. What were the tensions that emerged as the beginning science teacher of color developed equitable instructional practice in the SDE? How did the teacher negotiate these tensions?

To answer my first question, I analyzed his reflections and practices to understand how and why certain practices were taken up and why others were not.
In particular, my analysis focused on the teacher’s views of learners, learning, and teaching; enactment of science instructional practice, and shifts in his perspectives and practices toward more student-centered ones. For the second research question, I concentrated my analysis on the tensions and challenges he encountered as he engaged in this form of pedagogy.

By paying attention to the journey of the teacher’s development, the shifts in this process and his means of negotiating the challenges that arose I hoped to understand the teacher’s meaning-making process and adoption of alternate theoretical and instructional practices [Gutiérrez and Vossoughi, 2010]. Comprehending this process could provide significant implications for teacher learning and support within institutions of teacher preparation, induction, and professional development, especially for teachers of color.

As stated earlier, we defined equitable instruction as enacting student-centered practices that value, incorporate, and expand students’ repertoires of practice. I utilized this view of equitable instruction and the theoretical framework of CHAT to guide my analysis and identify my themes.

I identified five major themes that describe a set of instructional practices enacted by the teacher to design lessons that would meet equitable goals. The five themes identified were (1) setting learning objectives to center students in instruction, (2) organizing learning for expansive learning outcomes, (3) building authentic student-teacher relationships, (4) sharing cultural and historical aspects of science/scientific knowledge, and (5) reaching out to your community of support. Within each theme I first provide a narrative description of his process of development in order to answer my first research question. I then discuss the tensions and challenges that arise as
he engaged in this set of instructional practices, along with his process of negotiating these tensions.

Another point to note is despite the presentation of these themes as separate sets of practices, they are not clearly delineated sets but in fact are interrelated and overlapping. For example, in order to organize learning to support students equitably (Theme 2), the objectives of instruction (Theme 1) play a large role in this organization and the tensions associated with this are seen in both themes. Discussing issues of race, culture, and representation are taken into account in the object of instruction (Theme 1) and presentation of science in the classroom (Theme 4). I now present the discussion of the five themes.

5.2 Theme 1: Set objectives to center students in instruction

Andres expressed objectives of teaching in his reflection that extended the focus of learning from mere remembering and understanding content to include knowledge and skills that were valued in this world and by the students. He wanted his students to become critical thinkers asking “thought provoking questions or leading questions. . . [and] not just answer but [explain] why is that” (August 23, teacher reflection). He also wanted his students to understand the social impact and relevance of science, support their development of communication skills, construct evidence-based arguments, present information to a public audience, and build the study skills they would need to successfully perform on tests and access higher education. In the SDE, we co-created a lesson based on nuclear energy. We had discussed the objectives of the lesson during our planning and reflection sessions, and Andres expressed the
Andres: The focus then wouldn’t be [just] teach half-life, it would be [to] teach the discussion piece. Being able to talk about how this effects community.

(October 8, teacher reflection)

In the lesson, the students were asked to investigate the impact of nuclear energy in the world and community, and argue for or against the use of nuclear energy in their community. Half-life is a chemical concept related to nuclear energy and is a formula used to calculate the life of a radioactive element that produces nuclear energy. We designed the lesson with the aim of creating opportunities for students to learn the content and explore the relevance of chemistry in their own lives and the lives of the community. In the above quote, Andres shared that one of the objectives of the lesson was to highlight this aspect of nuclear energy and understand its social effects. The “discussion piece” refers to the learning objective of building students’ communications skills in constructing and presenting an evidence-based argument to support their opinions. Setting learning objectives that will enable the students to accomplish larger goals of schooling and achievement, especially toward higher education and improvement of quality of life, was important to Andres, as he shared in the reflection below.

Andres: The end goal again is getting them to learn the content so they can graduate, so they can further themselves and their family (August 17, teacher reflection).

Another aspect essential to learning objectives was to include student interest and motivation. In the quote below, I share Andres’s description of a lesson he created for his honors students in a previous semester. He had shared this story when we were
discussing our plans for the semester about creating lessons to bring in more student voices and leverage their interest to engage them in science. This activity, which he called “Friday discussions,” created a space for students to identify and discuss topics of interest to them that were also related to chemistry and the units they were studying.

Andres: I just remember from my honors class this past year I incorporated something new which was discussion, like Friday discussion topics. So, at the beginning of the semester students list what they are kind of interested in . . . in science . . . and some of these were not topics we picked but I wrote them all down. On a Friday we would pick one topic that they would research on their own time to discuss the next Friday . . . for 20 minutes. And we would talk about it and they have preset questions. It wasn’t related to what we were learning at that time, but it was teaching them just science communication and just being able to support their answers. (August 9, teacher interview)

In the above quote, we see that Andres’s desire to incorporate student interest in his instruction led him to design an activity with the objective of building skills in scientific communication and argumentation utilizing topics aligned to student interest in order to engage them. He also identified student interest and motivation by administering an introductory questionnaire at the start of the semester asking students their interests, out-of-school activities, and motivations for learning.

One of the major factors that influenced Andres’s setting of learning objectives was the motivations of the school and, consequently, the district. These motives were shared to Andres through various forms of meetings including professional development sessions, department meetings, and whole-school meetings. The primary
professional development Andres had received from his district and school was on setting and assessing student learning outcomes (SLO) and writing learning targets using Bloom’s taxonomy [Anderson et al., 2001, Bloom et al., 1956], respectively. In the quote below, Andres provides an explanation of the district’s implementation of SLO in his classroom that requires him to set a learning objective for his students.

**Andres:** We’ll have an SLO statement . . . [that states] what we expect of them. So it’s really like the main ideas. I think ours is wanting the chemistry students to be able to critically think . . . and [be] like good citizens, science citizens. (August 17, teacher interview)

The SLO is a tool provided by the district to teachers in order to maintain standards of accountability through data-driven decisions such as the “trends of the past few year’s classes. Are these chemistry students in general . . . coming in stronger in science? Are they coming in weaker? Are they coming in the same? And then . . . how much growth can we expect out of them? Where do we expect our students to end up at? Do we expect all of our students to get As, or some Bs, or mostly Cs?” (August 17, teacher reflection)

This is accomplished by setting learning objectives, collecting data through and analyzing data from assessments to accomplish the set learning objectives. In Andres’s department, this learning objective is determined by the head of department and then shared among all the teachers from the same discipline. They chose building critical thinking skills and scientific literacy as the main learning objectives of the semester.

The desire and intent for learning objectives that prioritize students’ interests and experience is in constant tension with issues of content and time. Andres often wrestled between setting learning objectives that were meaningful to the students, thereby
incorporating student interest and leveraging student experience, and maintaining the pace of instruction to complete the necessary amount of content before the end of the semester. Andres frequently expressed concerns about time: He wanted to ensure that he completed the required chemistry units in time. Pacing instructional time to ensure completion overtook the objective of pacing instruction to meet the students’ needs and pace. In the excerpt below, Andres shares some his concerns when asked to reflect on the week’s lesson during one of the reflection sessions we had together.

**Andres:** It’s getting really bad . . . the timing, the spacing of stuff. We are spending the time we need on the materials or on the questions and topics, but so much slower than I would like to be moving at both CP and honors. We should be maybe a day or two ahead by now, but I don’t know. (August 30, teacher reflection)

Completing the topics was essential to maintaining accountability with his department and school and ensuring all students were prepared with the content on which they would be tested. We see some of this dilemma in his discussion above about the Friday discussion topics, where he frequently mentioned that the topics were often not related to “what we were learning at the time.”

When setting objectives to guide his instruction, the content standards and pacing remained a priority. He often made instructional decisions and set learning objectives to ensure all his students had all the information they needed according to the standards and upcoming tests. The quote below is our post-lesson debriefing in which Andres shares the learning objective of the lesson on nuclear energy co-designed during the SDE.

**Researcher:** When we were planning this . . . what were the learning targets?

**Andres:** Definitely the chemistry behind it. If they could leave understanding what
half-life was, and the math behind it, if they could understand the series, the nuclear series decay, or the radioactive series, alpha, beta, gamma, positron, that’s kind of what I came in thinking.

Cause that’s what I generally teach, the math behind it. I also, I know I talked about the ethics of it, and that was like a piece that I had never really been able to address properly through lessons. (October 8, teacher reflection)

Andres’s previously set his learning objective for this unit on nuclear energy to focus on concepts such as half-life, radioactive series, and nuclear decay along with the computational and algebraic skills required to solve problems related to the unit, which Andres describes as “math behind it.” In the SDE, he maintained the essential focus on these concepts but expanded the learning objective to also explore the ethics of nuclear energy, thereby increasing the understanding of science from learning concepts to critically evaluating the social and ethical aspects of the unit in the real world.

5.3 Theme 2: Organize learning for expansive learning outcomes

In this theme, I discuss how Andres conceptualizes and organizes learning to support his students’ growth. This process of organization provides insight into how he chooses (or does not choose) student-centered practices that lead to (or do not lead to) expansive learning outcomes.

In the following excerpt, Andres shares his experience and thoughts about two students, Maya and Misha (pseudonyms). He had noticed that these two students, who
normally were disengaged in his classroom and struggled with reading and comprehension, were engaged in the reading activity he had organized.

**Andres:** I did this reading [in class] on a book called Homeless Bird. It’s by Gloria Whelan. It’s the first book I picked and I was like, “Oh, it actually is a really good story. I’m going to pick this for my lesson.” It’s about a girl who forgets [and] whose parents’ background is [from] India. [The] parents end up having an arranged marriage for her because, one, they don’t have much money. They have to sell their cow and stuff . . . and get all these different things. There is so much vocabulary.

I end up picking this book and I tell Maya and Misha like, “You read a little bit, then you read a little bit, then I read a little bit and we all talk about it.” I told the girls like, “Hey, let’s read it,” and then at the end I was like, “What do you guys think about the story?” They fell in love with the story.

Then the great thing about this is this was during the fourth block. Maya is a fourth block aide for another teacher, so I pulled her out of that class [to read]. The next morning . . . the other teacher sees me and is like, “Hey, how did everything go for the lesson?”

I was like, “It went great. I appreciate it so much.”

She’s like, “Yeah, no problem.”

She [then] tells me Maya actually ended up coming back a little bit later than she thought to her classroom, because [Maya stopped] by the library and [picked] up four books and she said she wanted to read books, these four books before Christmas.

Yeah. I was super-excited. I think I’m going to get them. I’m going to get them the book. (November 6, teacher reflection)
Andres felt good about his teaching when he noticed the activity he organized allowed for the students to engage in it, motivated them to learn more and develop important literacy skills such as reading and comprehension. He had organized this activity as part of an assignment he had to complete for the graduate literacy course he was enrolled in at the time of the study. He created a space outside the norms of the chemistry classroom to choose content and facilitate opportunities for students to explore their own interests and learn important skills at the same time. He had positioned the students in the center of his instruction. I do notice some missed opportunities for organizing learning, for example, leveraging Maya’s strengths and skills she would have developed as a teachers’ aide. However, this incident was in stark contrast to his regular direct instructional strategies with a focus on learning the chemistry content required by standards and testing.

In another example, Andres describes an instance where he worked with a student who was struggling with understanding the concepts and shares the steps he took to organize instruction to allow for multiple ways of learning and understanding. He shared this with me during one of debriefing sessions during Unit 5 on chemical reactions and types of reactions (See Appendix E for full list of all units taught during the semester).

Andres: “This is bull.” She didn’t say it loud, but I hear everything.

Researcher: Was it because she got a test result back or something?

Andres: Just frustrated with everything, just not understanding it, having a low grade, putting in some effort but then still not getting it. I took her outside and we talked for a bit. She really didn’t want to talk, she was really upset. Murmuring to everybody else like, “I’m not going go outside.” [Another student] was like, “Just go
outside, he’s just going to talk to you.” We went outside and I could tell that she
was so frustrated and angry, and . . . I started off like, “Look, I’m not here to yell
at you,” because I wasn’t. I was like, “I understand you’re frustrated, so tell me,
talk to me. What can I do to help you understand better?”

She was like, “I don’t know, just more practice.”

I’m like, “Well, let’s think of an example of another class you’ve struggled with.
What was it?”

She’s like, “Well, math.”

Then I was like, “Well, what happened?”

[She said] “Well, eventually, I got it.”

I was like, “Well, what was it?”

She was like, “Well, we just did a lot more practice.”

“All right. I’ll give you more practice. I can do that.” (November 29, Teacher
reflection)

In the above transcript, there are several different interacting practices and
perspectives being enacted. The first thing to note is that Andres is attuned to his
students’ academic needs and understands the emotional burden of students related
to school and academics. He immediately addresses it, not discounting her emotions
and frustrations, realizing they play an important role in building her confidence
with the subject and therefore her learning of the subject. He utilizes the one-on-one
conversation as a space to problem-solve together. He first figures out her sources of
frustration and asks her what has helped her before so he could support her in ways
that are most effective for her learning. He does this by providing more practice with
this concept, which is the same method that helped her understand and successfully complete mathematics problems. Toward the end of the conversation, Andres walks her through his understanding of the rules to help identify types of chemical reactions. For example, in the excerpt below, recognizing water as one of the products of a reaction helps to identify that the type of reaction stated in the worksheet followed “rule number four.”

Andres: We talked it out and that helped a bit, I think, just ease everything. Then, today I made sure that when we started working through this worksheet, I just stood beside her and worked through it step by step. What I had [her] do is first identify the title and identify the rule. I figured if we can break down the steps of each [problem] to figure out the problem . . . we’re scaffolding the learning, right. [She] knew this was a rule number four. She recognized water was present. I’m like, “All right. Well, what does the rule before say?” She had to go back [to] . . . a rule before for synthesis which she was really having a problem with realizing that M is a placeholder.

Then she’s like, “Oh, like X.” I’m like, “Yes like X. X amount plus the placeholder.”(Nov.29, Teacher Reflection)

The last three conversation lines show how an understanding of algebra (x as a variable and therefore placeholder of a numbered value) was essential to her understanding that the letter M in a chemical reaction or compound was also a placeholder to represent all metallic elements. For example, MOH could represent Sodium Hydroxide (NaOH) or Potassium Hydroxide (KOH) or Copper Hydroxide (Cu(OH)₂). Andres had quickly recognized this connection she made and utilized it to help understand the concept and the worksheet problems.
Andres begins to visualize the relationship between his instructional practice (how he organizes learning), student engagement, and, ultimately, student learning. Learning occurs as students engage in activities and practices that they find meaningful and relevant to them, as we note in the example of choosing stories that engage them or scaffold them through problem solving and allow them to arrive at their own understandings of the concept.

When we designed and presented the transformed Unit 3 lesson on nuclear chemistry, we organized learning to provide multiple ways and extend the opportunities students have to learn and communicate. For this unit, we created activities that provided students opportunities to explore the content collaboratively with peers, scaffold reading comprehension of the content, and support the practice of identifying relevant information through graphic organizers. Students presented their learning from various perspectives on different topics related to nuclear chemistry using evidence-based arguments and visual presentations. In the excerpt below, Andres reflects on the learning of students and whether we had successfully organized learning (instruction) to achieve expansive outcomes.

Andres: I think [the students] got some general ideas of nuclear chemistry. Whether they got the half-life stuff, or the series [of nuclear reaction], I don’t think that happened. But I think that the main ideas of what nuclear chemistry is and having them come up with an opinion did occur. I definitely think that was achieved. But the actual typical content, the science content, I don’t know how much of it. I think they have some maybe, good starting points now to then be able to discuss about it, but that’s about it. (Oct.8, Teacher Reflection)

Despite these instances of organizing learning that leveraged their interests or skills and provided opportunities for multimodal learning and communication that
led to expansive outcomes, Andres’s primary mode of instruction for the semester was direct instruction. In order to meet demands and concerns of pacing and coverage, he ensured that all the units prescribed for the semester were completed in time and students were aware of all the topics, had all the information on those topics for the test and had enough practice with the testing practice that they would succeed. He felt that direct instruction would be the most effective and timely way to deliver the content for students to understand. As seen in the above quote, during our planning of the lesson on nuclear energy, Andres expressed concerns about dividing up the content so that different groups of students would become experts for each sub-section rather than having all the students learn all the content that day.

Andres also constantly monitors students’ behavior as indicator of engagement and learning: On- and off-task behaviors indicate how engaged students are and whether they understand the concept being discussed.

**Andres:** As I’m approaching the group, there’s: Are they talking to each other? Do they quiet down? Do they speak up? Like what are they doing? Do they tune in back to the conversation that they should be having? That’s some of the things I’m checking just for behavior and just making sure [of] that management. I’m also checking in when I specifically ask them just I hear what they’re talking about at the moment and then either question what they said, make sure that their partner also knows what they said, especially if their face looks kind of like they’re kind of doing all the work, like one person doing all the work. (August 30, teacher reflection)

In the excerpt above, Andres notes body language and student behavior as a type of formative assessment. He explains how checking in with the groups serves as a tool for behavior management and assessment of understanding. He also notes how the
students work together in the group. Andres utilizes many different types of formative assessment in addition to exit tickets, showing of thumbs up or thumbs down for understanding, drawing on the whiteboards, and whole-classroom discussions. He also utilizes summative assessments in the form of unit tests given at the end of each unit.

5.4 Theme 3: Build authentic student-teacher relationships

Connecting to his students was an important aspect of Andres’s instructional practice that he constantly shared throughout the semester, and he was confident that it was his strongest skill: “connecting [to] the students . . . I think that was the easy part. I think that’s what I find to be easiest” (August 9, teacher interview). This remained a priority for him throughout the study. In his final reflection, Andres shared:

*The ability to connect with the students as well having been a graduate [of this school] and understanding some, though not all, challenges the students carry with them makes me feel that I best use my skills at this school.* (Final reflection, teacher artifact)

In his teaching philosophy, Andres articulated the importance of connecting with students and acting as a role model for them because of his shared experience with the students in this school:

"I feel that I can be a positive role model for all students given that I am a male, my native language is Spanish, I am multiracial, from a foreign country, and grew up in their community.” (2018 Teacher of the Year Application, teacher artifact).
Andres constantly shared his own background and experience with his students to demonstrate their capabilities, encouraged them to strive for higher education despite constraints in the system such as lack of financial support and to reject stereotypes often associated with students of color, and held them to high expectations. Sharing these experiences made Andres a valuable resource for students who came from similar backgrounds of culture, race, gender, or socioeconomic class.

Andres: I remember telling them, “Look, I went to college.”

So they’ll ask, I’ll tell them like, “Look, I went to [University].” And a lot of them did recognize [the University], “Like, oh my goodness. That’s a big university.” They still look at it and like, “Okay, so like, maybe I can never go to [University].”

And then I tell them my story.

I told them, I [did] not expect any money from [my] parents. Like, there was just no expectations I could get any help from them. So, everything I had to do was like, scholarships and loans.

Sharing his own experience of attending class and studying for the class also helped him connect with his students. At the time of the study, Andres was attending an online graduate course in literacy education, and he often shared his experience in the classroom with them.

Andres: And I also like it when they ask me about stuff. Sometimes, you know, one of the things they’ll ask me about is my classes, because they’ll hear me talk about my classes. They’ll ask me how the classes are going. . . . I don’t really complain about my college courses, but there will be things I mention . . . [like] how this professor kind of presented this [content]. (September 13, teacher reflection)

He made the effort to remember their names with their preferred pronunciation, avoiding the common racial microaggression of mispronouncing students’
names enacted by White teachers when interacting with students of color [Kohli and Solórzano, 2012]. He used humor and play to interact and connect with his students in order to develop relationships with them. He always made time for students outside classroom instruction time and frequently reminded his students to utilize this time to seek help.

He also paid attention to their emotional needs, supporting them when they were emotionally disturbed or needed reassurance to build confidence. He was also aware of the current social and political climates that can affect his students. In the story he shared below, Andres recognized the distress in a Latinx student after the most recent elections when the 45th President of the United States was elected into power.

**Andres:** I remember when Trump, the president, got elected. Rafael [a pseudonym] came in the next day. He came in during lunch, and he was kind of upset. He’s never really upset. In the classroom he was funny, but when he came in, I could tell something was on him. He just started talking about it. He just got real emotional about it. He didn’t cry, but you could tell he was getting choked up on the words.

He was like, “I just don’t know what I’m gonna do.”

*His situation was gonna get complicated because he didn’t know what kind of policies would be implemented that would challenge his access to a university.*

Andres recognized the distress the student shared, and because of his relationship with the student he was a person the student trusted enough to confide in. Andres values his students and the relationships he builds with them. He often leveraged his relationship to engage his students in the classroom. He utilized these relationships to “buy into him.” He believed that building good relationships would motivate students to learn the content to succeed in tests and academics.
Andres: Molly [a pseudonym] was talking to me yesterday or day before how she wants to get a new job and I was thinking in my head, “All right, she works at Sphinx.” And it’s on her questionnaire.

So that kinda information . . . I use it when I’m trying to make those connections with them. I don’t incorporate as much in the instruction but I feel like a lot of my teaching style is reliant on the making sure they buy the idea of me. I feel like if they buy into me, then I’ll be taking care of them through some of this content.

It’s not like I’m selling a bad product. It’s more like . . . I’m the medium which gets them the information that I know they need but they don’t know they need it. If they don’t realize how they need it and all I can tell them is, “This is for good.” “This is for college.” “This is critical thinking.” This is for this and that . . . [and if] they can buy into me and like “You know what, I’m gonna do it just because I like Mr. Andres and because I trust him.” . . . Then the effort that I’ll get might better than just someone who just will not. (September 13, teacher reflection)

In the transcript above, Andres shares his conversation with one of the students in his classroom. From the introductory questionnaire given to the students at the beginning of the semester, Andres is aware of the student’s responsibility after school. He uses this as way to start conversations and show interest in students’ lives to build “connections with them.” However, this connection with his students is not incorporated into the instruction. Instead, he leverages his relationship with the student to trust him and to engage in learning in the classroom because of this trust developed in the relationship. He believes that his students “invested [themselves] in it because [they] saw how much I invested in [them]” (August 17, teacher interview).

Trust and respect were essential elements in building relationships with his students. As seen in the quote below, Andres expresses the significance of “gaining their trust”
because this trust and respect encourages students to engage in learning organized by Andres.

**Andres:** I mean, I’m an adult. They respect that, and they know that. But I also, I guess I’m one of them, as you’re saying. I’m a human. I . . . also . . . can understand. So I think that’s important to gaining their trust. When you gain their trust, their attention, their respect, I mean that’s really all you need for a classroom. Students can struggle academically, but if you have the other stuff we can get them close enough to at least have some sort of success. (September 13, teacher reflection)

Despite emphasizing trust and respect in relationships, it was not a reciprocal process. Andres paid attention and listened to his students to build relationships but did not acknowledge the trust and respect in his instructional practice, often underestimating his students to lead their own learning or not acknowledging their knowledge and strengths because he assumed that he “knew [them] better than they know themselves.” Within the SDE, however, after the implementation of the second lesson, Andres shared how he now trusted students more with leading their own instruction:

**Andres:** [A] lot of them kept saying they were just happy it was different, different routine. I think they probably also mean that it’s kind of trusting them enough to be able to find the information. Jack really said, “I like to work at my own pace.” He got the work done.

I think they all benefited from the lesson. I think I’m just critical of a lot of things.

(October 8, teacher reflection)

Andres had assumed that leaving students to take on independent responsibility for their own learning would not succeed, but he changed his mind after he
witnessed it in the classroom when we created the opportunity for students to work on the presentations for nuclear energy at their own pace while still maintaining deadlines for the final day. Within the reflective opportunities created within the space of the SDE, Andres began to reflect on his relationship critically and how his view of equity, trust, care, and relationship has had an impact on his instruction.

**Andres:** I think historically, I’ve always cared for the students. I know that what they can bring in is important. As of recently, I see that that’s not enough. I don’t necessarily think that I’ve done anything on purpose, but I think that’s where the difference between equity and . . . What is it? Equal and equity, I guess.

I feel like I’ve been more on having equality than actually what I thought was probably more equitable in education, right? I’ve been considered evolved but if I’m considered evolved and treat them all the same, then that’s not equity. I think to some degree, I definitely limited the potential success for students.

Prior to this I don’t feel like I’ve taught with their cultures in mind. I think I have treated them differently, if that makes sense. I’ve definitely been mindful in how I treat students but not necessarily how I’ve taught. (Nov.6, Teacher reflection)

Andres’s perspectives on and assumptions about his students and how he evaluated their skills and created learning opportunities was based on his experience with his own teachers during his schooling. Andres shares a memory of a supportive teacher that advocated for him and ensured he had all the opportunities to succeed in science. Andres was a recent immigrant who had just transferred into this school from his previous school, which was a designated school for emergent bilingual students learning English. His teacher was White.
Andres: Fifth grade was really great [because I] had a really supportive teacher, which I think is also probably another reason somewhere in the back of my mind why I like teaching my teacher. She knew I was coming in with . . . not labeled ESL . . . but from the [ESL school]. But she saw me and she knew I was kind of smart and she put me into the challenge program, which is like the honors program of elementary school.

So that happened [in] fifth grade, so that was really supportive of her.

This teacher played an extremely important role throughout his school career. Andres expressed that he had a positive experience in school and in the science classroom because of the teacher’s support and high expectations. His teacher had advocated for the honors track because of the relationship she built with him. He still maintains a relationship with this teacher today. In his final reflection, Andres shared his understanding of how his experience and relationship with the teacher encouraged his engagement in science and teaching.

My joys of teaching science/chemistry stem from my own personal experience with science in high school and college. One of the most impactful . . . teachers that I had [who made the greatest impression on me] was my science teacher who taught me during three years of my high school experience. (Final reflection, teacher artifact)

The teacher has advocated for Andres to be tracked to the advanced course and this influenced his views of himself related to science and his experience in science. Teacher assumptions about students influence teacher practice related to advocacy in science, such as encouraging higher tracks for non-dominant students. Because of this essential relationship, I had asked Andres to share his views on tracking, drawing from his own experience. I provide the transcript of our conversation below:
Researcher: Since you’re also teaching honors and CP, what do you think of tracking? And I remember you had also experiences of tracking. . . . So coming from all of that, what do you think?

Andres: Logistically I can see the benefits of it. I think it boils down to class sizes. If we have a large class size of varied spectrums of capabilities of students, of what they’re able to do, you’re always gonna have one student who’s either struggling, or one student who’s bored out of their mind. So I think . . . tracking, separating, chunking some of these students is beneficial to get all the students the opportunities they need, and pushing them as far as they’re able to.

I think though that the system is not perfect, and I do feel like there are items when students aren’t correctly placed in the right group. Often times I think it’s a lot of learners of black, Hispanic, they’re not as easily moved up because of different behaviors that are not similar to that teacher’s recommendation, because they might think a loud student’s not a smart student.

Researcher: Yeah. Exactly. Do you think tracking is equitable at all? You think there’s a better way to do tracking? That’s my understanding from what you were saying. Is that right?

Andres: I think it should be more conscious of separating student [ability rather than] behaviors . . . what might be considered as a disruption. . . [because it is assumed] they’re not intelligent.

A few months ago, I was looking at some data from the school, that’s from the federal government I think. It recorded our school data on discipline, number of students AP, honor classes, stuff like that. The discipline. Those who were getting more ISS, which is in-school suspension, are often [dis]proportionately . . . it was like higher percentages of those . . . were minorities. You know, something’s not right.
**Researcher:** So you do at least notice it. Like, there is definitely some sort of discrimination like the system itself perpetuates.

**Andres:** I think it’s also the lack of awareness of the teacher . . . and I’ll say this. I don’t think it’s intentional most of the time. (August 17, teacher interview)

In the above transcript, we note Andres’s tensions related to the system of tracking. He viewed tracking as an effective strategy to separate children based on ability in order to equitably serve them by meeting their unique needs. However, he had noticed how teachers’ deficit notions and awareness (or lack of) have an impact on tracking of non-dominant students in inequitable ways. He remarked how this system is inequitable because of the disproportionate presence of Latinx or Black students in the classroom. His statement was confirmed by the data he found that illustrated how school disciplinary practices are disproportionately administered to Black and Latinx students. The data he refers to is data from the website Miseducation, an online informational website that presents data on racial disparities in learning opportunities and disciplinary practices in visual forms [Groeger et al., 2018].

**Andres:** If they keep being the ones who are constantly written up, treated that way, they are going to start getting some of this distrust with people in power or certain groups of people, authority. This distrust, it’s rooted in experience. I think that’s what the long article talks about too. . . . Historically speaking, this is why they’re so stressed. I think that’s some of the sociocultural outcomes. (November 6, teacher reflection)

Related to this awareness of inequitable structures such as tracking, Andres critically discusses how school practices have had a negative impact on students of color, disproportionately creating “distrust” among the students. He shared this realization during one of our reflection sessions after he had a read a case study that
described the experience of a Hmong teacher of color in a school. The articles he refers to in the quote above is the case study I shared with him that relates to the teacher of color’s experience with students from non-dominant groups and the distrust created by systems of power such as schools.

5.5 Theme 4: Share cultural and historical aspects of scientific knowledge and practice

During the first stages of the SDE when we began to plan for the semester, Andres had shared his interest in addressing cultural issues, such as issues of race, in the science classroom. However, he had also shared that despite this desire, he found topics such as gender or race difficult to bring into the classroom because they are generally not part of the required content (as determined by the state’s standards and the school’s policy).

**Andres:** It’s difficult to naturally address gender, race, or even religion [in science]. I think those are tough to address in science especially chemistry classrooms because it so outside the norm of the standards. (August 17, teacher interview)

Andres, despite initially struggling to see the intersections of science and culture, the example below shows him expressing views of teaching science in ways that would include social or cultural aspects.

**Andres:** I know recently what’s on kids’ minds is lead with Flint, Michigan. I’ve looked into how we can incorporate that more than, “Oh there’s lead in Flint, Michigan.” I think that could be an avenue that I want to explore, which is actually a few weeks into the semester.
If we can explore that and how we can talk about why the plumbing in that area is so poor there. Why is it lead infested? Also, what kinda groups are mostly affected and how that could be a structural [issue]. . . . Not to sound crude, but are they just screwing those people in that area? (Aug.23, Teacher interview)

In the SDE, Andres had co-designed a lesson on the scientific and engineering practice unit in which we utilized data related to racial representation in the field of science education and careers. This was done with the purpose of sparking discussions that could tie together race (culture) and science.

**Andres:** I think that discussion would be interesting and hearing what they think. I don’t know how many of them have had the opportunity to talk about race in the classroom or mix the two, science and race. (August 23, teacher interview)

Historical perspectives are as important as cultural perspectives in teaching and learning science, but Andres did not bring in historical perspectives because of the culture of his department: The community of teachers in the science department prioritize completing the content required of the two science courses necessary for the science college track.

**Andres:** We’ve cut out the history of it. That’s because the other classes have as well. I’m like, well the history is important, but the pace of what all needs to be taught in Chem One. . . . I need to find, cause I’ve gone through and I’ve determined what is taught in Chem One versus Chem Two. We cover so many more standards than Chem Two, so because of that added pressure of covering a lot more in Chem One, I’ve got to be very particular with what I teach. (September 20, teacher reflection)
Andres believes it is important to include historical perspectives in the science classroom. In the SDE, for the first lesson, Andres had started the lesson with an informal discussion of famous scientists to encourage students to think about historical representation of scientists in the field.

**Research:** So you focus on the current content versus the history?

**Andres:** Yeah, which is unfortunate ’cause that is definitely important. I think those, as we’ve talked about, like so these are the famous scientists. (September 20, teacher reflection)

This could explain why Andres did not engage in practices that allowed for more multicultural views of construction of scientific knowledge. This is evident in his instructional practice related to science and engineering practices: He often provided students with the list and never addressed these practices explicitly in the classroom later on.

**Andres:** Prior to this I don’t feel like I’ve taught with their cultures in mind. I think I have treated them differently, if that makes sense. I’ve definitely been mindful in how I treat students but not necessarily how I’ve taught. (November 6, teacher reflection)

In spite of including social, cultural, and historical aspects in science, Andres still maintained monocultural or universal views of the nature of scientific knowledge. I provide two examples below that illustrate Andres’s understanding of science: science as discovery of truth and science as a body of theories.

*I find that science challenges a student to use critical and spatial thinking as well as having the ability to understand theory and being able to apply the theories. The*
near certainty that science can provide as well as discoveries and challenges to what's accepted as correct is exciting. (Final reflection, teacher artifact)

This universal view, enacted in his practice, had an impact on student learning. Due to the historical and cultural practice of science being taught in discrete, separate, and unrelated ways, students shared a similar disjointed view of science where they saw no relationship between algebraic practices, chemical concepts, and, consequently, how scientific knowledge is constructed. I provide two example excerpts below that illustrate his view of the students in his classroom. In the first quote, students express ideas that demonstrate their lack of understanding of scientific practices of the science community: Data is often only seen in history or math classrooms and therefore the students mistakenly assume that it has no relationship with science.

Andres: When you talk about scientists, and I think someone said like history class. All right, well when do you use data? And a lot of them can say history and they would say math. I'm like, “Well, you haven't used this data, have you?”

(September 7, teacher reflection)

In the quote below, Andres shared the frustrations of his students and himself because of the lengthy engagement in computational concepts of chemistry such as calculating density, which students do not see as part of science but a math class enacted in the science classroom.

Andres: We’ve already been doing all this math and they’re tired and they want to do chemistry. It was a thing where they were just really exhausted, not because of the conversation, but really when are we gonna get to chemistry? They need something and unfortunately like with chemistry, like you don’t really get any wet labs. (September 7, teacher reflection)
After engaging with a variety of literature such as sociocultural perspectives of science in the SDE, Andres began to critically reflect on the nature of science, the role of culture in science, and its implication in his instruction:

*I have started to acknowledge how science is generally thought through a Western lens, without much consideration of other perspectives. A better understanding of how different cultures/regions/groups of scientists view scientific principles could translate for a better ability for me to consider students’ different backgrounds.*

(Final reflection, teacher artifact)

5.6 Theme 5: Reach out to your community of support

For Andres, the community that supported him and influenced his practice in both positive and negative ways included the district and school administrators, school counselors, the department head of science at the school, peer science teachers, and me, the researcher. These communities created norms valued by most members, which in turn influence and govern the practices of the members, including Andres.

The first system of support is the school. I noted a lack of school support with respect to equitable science instruction. When I examined what occupied his time and how he was supported, I observed that there is a systematic lack of prioritizing student needs, equitable instruction, and provision of support to teachers. Andres describes his first week of school where, before the students arrive, all teachers attend meetings to plan and set up their semester. These meetings are a way to see what the school prioritizes.
Andres: We did have some tactical meetings throughout. So we had some about safety, talking about legal procedures. Religion was a big one that came up this year.

What else? We have a new lunch schedule. Talking about smart lunch . . . I think the reasoning behind it is that all students in that class have to show up, of that lunch period. And only the ones, so the ones who don’t have anything to make up or are passing, we dismiss them. Everybody else who’s failing or needs to make up something stays behind.

The school determines the use of the teacher’s time, and for Andres the focus was not on instruction but on school motives and priorities such as religion within the school space or the introduction of a new program: the smart lunch. Smart lunch occurs during the students’ recess where half the duration must be dedicated to academics: Students who are failing or have missed the work assigned by their teachers could utilize this extra time of instruction to improve their academic performance.

A similar form of support was seen in his department. There was a lack of peer and department support in planning science for equity.

Andres: They would’ve finished in a meeting with my chemistry people [on] Wednesday.

Throughout the school year we’ll informally check in with each other, kind of like in the hallway. Just, “Hey, where are you at? Where am I at?”

But the lesson plan, I think, is [always individual] for the most part. Maybe more just for me. And then the other two chemistry teachers, who also teach other courses, they kind of collaborate a little bit more. (August 17, teacher interview)

Andres had regular meetings with the department and also interacted with his peer teachers. The teachers do have a sense of community, but it mainly serves as a
source of accountability rather than collaboration. In his department, teachers who had built relationships on their own with their peers would collaborate. Andres did not have such a partner despite wanting “somebody to talk to about this” (October 11, teacher reflection).

This was evident when he reflected during the SDE on the working relationship between the researcher (myself) and him. He appreciated and desired a peer who was “someone to bounce ideas off of and then kind of hold me responsible” (October 11, teacher reflection).

The collaborative relationship we built also highlighted the challenges that arise when Andres has to manage the entire class on his own. Because we co-taught the lessons Andres found “having two teachers helped address some of those needs and concerns [of the students]” (October 8, teacher reflection). This was important for Andres especially when he and his class were experimenting with new forms of teaching and learning.

The final members of his community are the parents of the students and the local community of the school and neighborhood. Andres is part of this community as he was raised here, attended the same school, and resided in the same community. Andres made the effort to contact parents as partners to help with the learning of his students. Andres shares his memories of working with the parents when he called them to discuss the students. These conversations involved discussion about both the students’ successes and struggles in the classroom:

**Andres:** I remember many conversations where parents are like, “Thanks so much for calling. I appreciate it.” I remember that and I just feel like I’ve done a poor job
Despite the initial relationship with a few of parents, due to a hectic schedule, especially with the addition of a master’s course while teaching and engaging in the SDE, Andres had not been able to continue to build strong relationships with the parents.

**Andres:** I’m going to keep blaming the fact that I’m busy on how poor of a job I do in reaching out to . . . the parents of my students and the community members.

I don’t once I’m done with my master’s but I think too because . . . I only thought about myself. I don’t know how well other teachers are doing. I don’t know how well I’m doing a good job like, “Hey, we have this,” like actually calling and canvassing essentially like, “Hey, we got this event. Come on out. I’d love to see you.”

(November 6, teacher reflection)

Andres also lacks relationships with the community. He does reach out to parents of his students but only to help manage student learning. He had regularly expressed deficit notions of the community the students reside in.

**Andres:** [Compared to] other schools . . . where the students don’t have, I’ll say it just roughly, have a rough life.

I remember 80% poverty, but really we should be higher. I think the new numbers are average for the zone, but it’s got zones of students who aren’t coming here. But yeah, it’s pretty high poverty and also rough home lives.

[Students come from] single-parent homes or grandparents who are their legal guardians. So I think understanding their situation is not always just about the
academics. They might be having something going on. I feel like my philosophy of teaching is there’s definitely a thin boundary, that thin boundary of being a teacher versus a friend. And I think I’m understanding. The kids come talk to me, but I also keep them to a high standard. I expect a lot out of them. (August 17, Teacher interview)

Andres understands the challenges that students face when they do not come from dominant or privileges families, yet he only views the families as lacking and not as a resource. This view begins to shift toward the end of the SDE.

*Through the discussions you and I had, I kept realizing how easy it was to put the “blame” on the parents or students instead of looking at how the schools weren’t doing what was necessary for our students.* (Final reflection, teacher artifact)

In the SDE, through critical reflection and engagement in theory, with my support, Andres began to notice how his language and practice focused on what parents or the communities lacked or did not do and instead shifted to what he and the school could do to engage the community to support the school.
Chapter 6

Discussion and Conclusion

6.1 Overview

The purpose of this study was to collaboratively design, develop, and analyze student-centered equitable science pedagogy. I examined the process of a beginning science teacher of color engaging in perspectives of equity and developing student-centered practices as we designed chemistry units for expansive outcomes. I discussed this teacher’s learning process and development of practice within the context of the five major themes to help illustrate and understand this learning process.

In this study, my research questions are:

- How did a beginning science teacher of color learn and develop student-centered equitable instructional practices within the space of a SDE?

- What were the tensions that already existed and that emerged as the beginning science teacher of color developed equitable instructional practice in the SDE? How did the teacher negotiate these tensions?
The five themes identified were (1) setting learning objectives to center students in instruction, (2) organizing learning for expansive learning outcomes, (3) building authentic student-teacher relationships, (4) sharing cultural and historical aspects of science/scientific knowledge, and (5) reaching out to your community of support. These themes represent collections of instructional practices that enabled him to explore and engage in equitable instruction. In this chapter, I discuss the findings holistically to develop deeper understandings of these sets of practices to help answer my two research questions. I discuss the common features I found across the five themes in order to illuminate the essential characteristics of enacting student-centered equitable instruction. I then present implications of these findings for teacher education and finally conclude this chapter and study.

6.2 Discussion

With respect to the first research question, which focuses on teacher learning and development of practice, we found that as the teacher began engaging in equitable forms of instruction, he established learning objectives and organized learning to place students at the center of instruction. He also valued building authentic student relationships, shared cultural and historical aspects of scientific knowledge along with the standardized curriculum, and reached out to this community of experts for support and guidance. However, this learning process was not smooth or linear.

Related to the second research question, contradictions and tensions are inherent in this learning journey because equitable instruction positions itself deliberately in contrast to traditional school and science practices [Roth et al., 2009]. Schooling and science education historically have existed as cultures of power that have framed
how science is defined, presented, and taught [Barton and Yang, 2000]. Science is often presented as a pre-existing body of facts discovered by mostly White males, not reflecting the true practices of and the diversity in the community of science [Eisenhart et al., 1996]. Science is discussed and taught as objective, rational, and universal and devoid of any cultural subjectivities. In contrast, science instruction geared toward equity acknowledges science as a human practice that is subjective and multicultural. Focusing on contradictions illuminates this culture of power, so the intent of my second research question, which focuses on contradictions, is to extend our understanding of teacher learning and adoption of equitable practices.

Andres encountered several contradictions within himself and with his practice, which he at times negotiated as he shifted his instructional practice and perspectives from normed practices to equitable and expansive ones. His negotiations did not always lead to equitable outcomes for students in spite of his intention and desire for these outcomes. The findings revealed tensions between prioritization of student interest versus standardized content in setting objectives. There were also tensions between creating opportunities for alternate versus traditional pathways of learning. I noted contradictions also in the teacher’s perspectives on tracking, view of trust in student-teacher relationships, and understanding of the nature of science. The final contradiction, which was most significant for the teacher, was his relationship with parents and community members. His relationship with the local community was significant because we noticed a shift in the teacher’s perspective on the families of the community over the course of the SDE. As discussed earlier, the teacher began to focus on how both he and the school could create spaces that are inviting to community members where they are positioned as valuable members and experts rather than viewed as the main problem behind the lack of a strong and supportive community-
school relationship. Despite this “uneven progress toward equitable science teaching” [Bianchini and Cavazos, 2007, p.586], we can learn from the successes and challenges of this teacher. I move away from evaluating the “effectiveness” of teacher practice or the intervention’s impact of equitable instruction and instead focus on the developmental pathway of the learning process documented in the process of change in the teacher [Gutiérrez and Vossoughi, 2010]. In this study I also hoped to engage the teacher in respectful and empowering ways: Rather than analyzing data and presenting it to show how the teacher succeeded or failed or what the teacher had or lacked, I focused on the strengths the teacher brought to the design of instruction and an honest description of his “uneven” journey that is inherently built of contradictions, thus presenting a “narrative of engagement” [Rodriguez, 2015, p.448].

I present my discussion as the synthesis of not only the five themes but also a synthesis of the two research questions. From a CHAT perspective, learning is a process that occurs as we construct and resolve contradictions that continually emerge in human practice [Engeström and Sannino, 2010]. Therefore, despite two distinct research questions, learning and negotiating tensions are related and can provide insight into teacher adoption of equitable practice when discussed in conjunction with each other. The two research questions were valuable in organizing and analyzing the data, yet there is value is understanding development of practice in context of the contradictions that exist or emerge.

As we look across the five themes, we learn that to enact equitable instructional practices, the first and most significant step is to start with the students’ experiences and skills [Bianchini et al., 2003, Gutierrez et al., 2007]. This means valuing students first-in the objective and organization of instruction-before the content.
The first step in designing or planning for a lesson or choosing a particular instructional practice is the identification of a learning goal or the object of activity [Ko, 2012, Hammons, 2017]. This is often the tool teachers use to select and organize materials, procedures, and assessments for instruction [Mager, 1984]. “It is exactly the object of an activity that gives it a determined direction. . . . The object of an activity is its true motive” [Leontiev, 1978, p.62]. Motives are essential because they orient an activity and the consequent actions taken up by the subjects within this activity [Roth et al., 2009]. Learning occurs during participation in the activity and therefore identifying and defining the motives is an important action step because it determines how subjects participate and, therefore, learn. From a CHAT perspective, these motives are not merely the learning objective set for the day’s lesson but are also reflective of the “societal determinations” of schooling and science education [Roth et al., 2009]. The objects chosen indicate larger motives of why science is or should be taught in the particular form currently enacted in classrooms.

Despite the desire and intent for learning objectives that prioritized students’ interests and experience, there was a notable absence of student voices and inclusion of student interest in constructing learning objectives of the main chemistry instruction. This was not only reflected in the teacher’s practice, but also in the motivations of the school and department that were conveyed to the teacher through formal and informal meetings. During the co-design process, the teacher and I constantly negotiated attempts to maintain a balance between the two priorities of the students and standardized content.

We often design science curriculum and instruction for equity through bridging student lives with school science culture through relevant science content [Rivera Maulucci,
2010]. However, maintaining this bridge does not challenge the culture of power inherent in school science, which causes tensions that often push teachers to prioritize standardized content over the interests of students. These standardized curriculums often reinforce the discrete, non-cultural views of science. Teachers are forced to comply through teacher accountability and standardized testing [Sleeter and Stillman, 2013]. While reform documents often mention and encourage equitable instructional practices such as connecting to student lives or project-based learning, the rigidity and compliance required by the standards and limited time do not support teachers and they fall back on traditional inequitable forms of instruction [Sleeter and Stillman, 2013]. This was evident in Andres’s experience.

From a CHAT perspective, learning occurs when individuals are engaged in activities that serve a purpose and fulfill a societal need and when learning is the expansion of one’s agency or possibilities of action [Roth et al., 2009]. When we organize learning in ways relevant to student lives and the communities they are members of, simultaneously increasing agency, we create a science education that is truly “science for all,” and this begins when we prioritize students from the start of instruction: the object of the activity.

Another important aspect of equitable instruction is identifying and challenging deficit and dominant views. Within the context of this study itself, numerous perspectives interacted and contradicted one another due to the dominance of certain views such as universal science or what it means to be a well-behaved or smart student. Evident in the teacher’s practice, the dominant views of science and school narrowed definitions of who is a successful or a smart student, and subsequently deficit views of students continued to be perpetuated through discourse and practice, despite in-
intentions for equitable instruction [Carlone et al., 2011]. Traditional notions of what it means to be smart and well-behaved became the norms against which alternate cultural identities and associated practices are seen as inappropriate, disruptive, or inadequate. Even with claims of trust, care, and respect in a relationship, deficit views of non-dominant students have a negative impact on their learning, as they are implicitly enacted through teacher practice. Teacher assumptions play a large role in building authentic teacher-student relationships and consequently instructional practices to support them meaningfully. Students, especially students of color, have often been underestimated and therefore under-taught [Delpit, 1988a, Gutierrez et al., 2007]. Conversely, teachers advocate for and teach with higher expectations when they assume the students are "strong," "smart," and "well-behaved." These assumptions lead to adverse effects such as Latinx and Black student being disproportionately recommended for lower tracks in science.

Another notion that must be challenged when designing for equitable instruction is the universal view of science. Due to the popular and common understanding of science as universal and devoid of subjectivity, culture, and history, teachers find it challenging to see how science could serve students in equitable ways. From a universal perspective, science is regarded as an intellectual activity with the object of finding the "truth" that is not affected by cultural differences such as class or race [Siegel, 1997]. In contrast, equitable instructional practices support multicultural science that challenges traditional, Western notions of what constitutes the content, process, and discourse of and participation in science [Harding, 1998]. This was evident in the reflection of the teacher in the SDE, because he continued to maintain the divide between science and the students: Even though we presented content in a manner that was relevant to students, it still did not begin with students’ motivations
to present science in ways that would serve them instead.

Due to the nature of equitable instruction and its challenge to dominant ideologies, engaging in this transformative process is filled with contradictions and tensions [Gutiérrez and Vossoughi, 2010]. Embracing contradictions as spaces or opportunities of learning is a characteristic feature of the methodology and framework in this study. In this study, Andres began to realize and appreciate the importance of the tensions that arise when engaging in transformative practices.

An element of equitable instruction that is essential to the development of such practices but is undertheorized is building authentic relationships. If learning is joint and distributed, then we must encourage authentic relationships with students, other teachers, the local community, and researchers to enhance learning and knowledge of equitable instruction. Relationships between students and teachers have recently received attention due to their significant association with academic achievement and engagement in learning activities [Roorda et al., 2011]. Building authentic and nurturing relationships is also the first step in developing equitable pedagogies [Valenzuela, 1999, Rivera Maulucci, 2010].

Authentic relationships are built when we respect and trust students and allow them to have a voice and lead their own learning pathways. Building these relationships and getting to know his students were important to Andres, but he separated it from his instructional planning and practice. He wanted his students to trust and respect him enough to remain engaged in the classroom so that they could succeed in academic assessments. This refers to a more aesthetic care [Rivera Maulucci, 2010](Maulucci, 2010), where teachers expect students to care about education. This is in contrast to authentic care [Valenzuela, 1999], where students expect to be genuinely cared for and
nurtured to succeed in ways that are meaningful and relevant to them. Building and leveraging relationships with students is especially important for students of color because the teaching force is primarily White, and students often do not see role models that look like them [Mensah and Jackson, 2018a]. Male role models of color are an important aspect of equitable instruction because men have often self-reported that they chose certain career paths, especially teaching, because of a role model with their shared experience [Vasquez, 2015].

The SDE also facilitated opportunities for the teacher to engage in critical reflection on his own experience and practice, along with formal theories of learning. Critical reflection is the process of reflecting on texts within the moral, political, social, and ethical contexts of teaching [Howard, 2003]. This form of reflection is considered significant to issues of equity and culture and is essential to improving learning opportunities and outcomes for non-dominant students [Gay and Kirkland, 2003]. An important element to the critical reflection was viewing the teacher as a transformative intellect [Giroux, 1985] “capable of engaging in critical reflection, questioning choices they make in their classrooms, and in doing so, considering which tradition of schooling might be revisited to order to better meet the needs of a diverse group of learners” [Fowler-Amato and Warrington, 2017, p. 360]. This perspective extends into practice by supporting the teacher in exploring formal critical learning theories and their possible application. Andres was encouraged and challenged to critically think about his practices and use powerful “literacies to reconstitute self and restructure self in the society.” From his readings and reflections, Andres began to adopt more equitable practices, question inequitable structures, and shift his perspective of students away from deficit notions.
6.3 Implications

The research community has recognized the need to provide instructional support to different groups of students by recognizing, valuing, and integrating these students’ cultural experience and practices. This is especially important for secondary school students, who are often not the focus of strategies and interventions for equity. Without bringing in students’ lived experience, equitable outcomes for students of color, such as high academic scores, placement in honors courses, positive science identities, healthy cross-cultural peer relationships, and, most importantly, a sense of identity that is empowered, are challenging to organize for [Carlone et al., 2011, Gutiérrez, 2016, Lee and Buxton, 2010].

The aim of the equity-oriented and design-based approaches of the methodology utilized in this study is to ensure that the primary focus of attention is on building student-centered practices where students are brought to the center of and remain central to teaching and learning. This study aimed to contribute to the literature on teaching science and inform instructional models of science education for students of color and teachers of color. Even when strategies do not reach their object of equity, this failure can be illuminating in the process of designing equitable instruction [O’Neill, 2016].

One of the biggest implications of this study is the role of teachers of color in equitable instruction and support of students of color. We are beginning to see studies that document the learning experience and practices of teachers of color in teacher education and education for equitable instruction. It is essential for the research community to continue along this direction and expand to provide more nuanced and diverse understandings of teacher learning and therefore teacher education programs.
Teacher education programs and the majority of the teacher population remain dominated by White perspectives.

Another common mistaken assumption is that teachers of color are often assumed to understand and engage in equitable instruction due to their lived experience of discrimination [Carter Andrews et al., 2019]. This erroneous assumption leads to underprepared teachers of color, which further aggravates the issues of Whiteness in teacher education [Mensah and Jackson, 2018b].

Engaging teachers as intellects in theory is also another implication for teacher education [Ladson-Billings, 2001]: engagement in theory and critical reflections and as designers of curriculum and instruction. Historically, teachers are not positioned as intellects or agents of change and rely on “fallback” strategies such as direct instruction for memorization and pre-packaged strategies developed by external stakeholders and view equity and inquiry as add-ons rather than central to science teaching. The SDE provided multiple opportunities for the teacher to engage in reflection about his practices and the perspectives of theory. Teachers and relevant stakeholders are often not provided with multiple opportunities to reflect on their practices [Gutiérrez and Vossoughi, 2010]. Critical reflective practices are essential to transformation of deficit views and inequitable practices. We must position teachers as intellects and organize learning to they can engage in critical reflections about their own identities, biases, and practices.

Finally, an aspect that is beginning to gain attention but has not yet been discussed in relation to teacher learning is the emotional well-being of students and teachers. Very little is known about how student-teacher relationships and engaging in equitable practice influences the personal lives of teachers from a well-being perspective and
the role of emotion in teaching and learning [Spilt et al., 2011].

From a CHAT perspective, emotions are essential to cognition and are expressions of the body that have an impact in participation in an activity [Roth et al., 2009]. In this study, it was evident that the teacher also valued student emotions along with their academic performance. This trait of learning is under-theorized in science teaching and learning. Future studies could further examine the role of emotion in both student and teacher learning.

Related to emotion and well-being, teacher stress is a common issue and interferes with effective teaching of students. However, emotions and well-being are not often considered when examining teaching and learning, especially in science education, as science derived from a Western perspective is considered to be objective and lacking emotion [Bellocci et al., 2017, ?]( Ingold, 2011). The lack of attention paid to health and well-being in Western science education is due to its origins in the Cartesian duality, where mind and body exist as separate planes, with the mind considered the priority or more important than the body [Merleau-Ponty, 1968]. Throughout the semester, during different instances of transforming his practice and interacting with his students and me, I noted that Andres often felt stressed with juggling everything occurring that semester. Nankin’s [I., 2016] research has shown how the tensions of teaching such as lack of institutional support or conflicting pedagogies, which are often associated with teachers engaged in equitable or social-justice oriented pedagogies, cause teacher stress and diminished well-being. Due to increased awareness about mental health and learning, researchers have begun to explore stress and decrease in mental health associated with individuals working toward social change. Social-justice fatigue is defined as “the physical, mental, and/or emotional toll incurred
through advocating for social change while serving as an agent of an institution of higher education” [Furr, 2018, p. 2]. I argue that equitable instructional models are necessary in order to value both students’ and teachers’ emotions and well-being.

6.4 Limitations and Steps for Future Research

I have only addressed a small aspect of equity through the lens of race. To develop richer understandings, it would be worthwhile to address concepts of identity and its issues and its intersection with science. I did not explore concepts of gender, class, or even the politics of the English language in this study. These would be my next steps to advance from the initial findings in this study.

My study also was only conducted over a short period of time. Longer studies such as ethnographies can be valuable for researchers, building stronger collaborative relationships with the teacher and following a teacher’s or even a student’s journey to see how this development process continues to take place and to see where it leads to for our teachers or students.

Finally, to sustain the model and practice we have developed, the teacher and I have remained in touch to continue to reflect on our practices and to build our relationship. We also have planned to meet over the summer to maintain this process and possibly design a science curriculum for his upcoming semester with student-centered practices embedded in his instructional practice.
6.5 Conclusion

The research community has recognized the need to provide instructional support to different groups of students by recognizing, valuing, and integrating these students’ cultural experience and the practices they have developed. Without bringing in students’ lived experience, non-dominant students will not encounter equitable outcomes such as high academic scores, placement in honors courses, positive science identities, healthy cross-cultural peer relationships and most importantly, a sense of identity that is hybrid and empowered in its hybridity in science [Carlone et al., 2011, Gutiérrez, 2016, Lee and Buxton, 2010].

The purpose of this study was to understand the process of learning to design for equitable science classroom instruction. The study aimed to contribute to the literature on teacher learning and education and to inform instructional practices for non-dominant students that are equitable. The equity-oriented and design-based approaches of the methodology utilized in this study ensure that the primary focus of attention is on equity and building student-centered practices.

This research study engaged the participants in a process that encouraged them to think about what a meaningful and successful science experience means to them and how we could accomplish this agenda collaboratively within a science classroom. The outcomes of this study include a description of teacher support sessions along with the supporting material, lessons plans that attempt to center student lives, a model that could guide instruction to value and expand students’ practices, and findings that illustrate the process of developing these materials and the learning that occurred as we pursued the goals of the study. The findings indicate that in order to teach science in ways that are student-centered we must build authentic relationships,
pursue motives that are relevant and valuable to the student, expand learning outcomes, share cultural and historical aspects of science and reach out to a community of support. This process of engaging in equitable instruction is a slow and uneven, yet it is essential to mainstream and widespread adoption of equitable science teaching practices that better serve non-dominant students. The implications for science instruction and teacher preparation are to embrace contradictions as opportunities of learning, engage in critical reflection, consider emotions and well-being as essential aspects of learning and most importantly, challenge deficit notions of students and dominant notions of school and science.
Appendices
Appendix A  Methodology Flow Chart

Methodology: Social Design Experiment
Purpose: To learn to design student-centered equitable science instruction. Theory: Cultural Historical Activity Theory (CHAT)

Student-centered equitable science instruction (SCESI)
Teacher support
Elementary Units

Lesson 1: Underrepresentation in scientific community and science & engineering practices
Lesson 2: Nuclear power plant community hearing

Q1: How did a beginning science teacher of color learn to develop SCESI within the space of a social design experiment?

Primary Data Source
Classroom observations
Researcher field notes & video recording
Teacher interviews
Teacher reflection & debriefing

Data analysis: Thematic analysis

Q2: What were the tensions that already existed and that emerged as the teacher of color developed equitable instructional practice in student design experiment? How did the teacher negotiate these tensions?

Primary Data Source
Classroom observations
Researcher field notes & video recording
Teacher interviews
Teacher reflection & debriefing

Data analysis: Thematic analysis

Enactment of practice shift in practice views of learner, learning, & teaching
Appendix B  Flow chart depicting the three phases of SDE and microcycles of analysis

Phase 1 Construction of local instruction theory
   (Design learning activities for an equitable science classroom)

Phase 2: Microcycle of Analysis and Revision of Local Instruction Theory

The flow of
Implement → Revise → Reflect

is applied for Lessons 1 and 2

Phase 3:
Final Analysis and Revised Construction of Local Instruction Theory
   (Design of Equitable Science Classroom)
Appendix C  Illustration representing structural aspects of SDE, with student as subject, utilizing activity triangle

Data set, graphing tools, worksheet, informational sheets, community-based or project-based lesson, role-play, Padlet for anonymous responses, PowerPoint slides for presentation, graphic organizers, groupwork and peer evaluation, feedback questionnaires, whole-group discussion

Respect, collaboration, on-task behavior

Researcher, teacher, peers, school administrative staff

Teacher and researcher as co-teachers, teacher and researcher as facilitators, students as collaborators, students as evaluators and communicators of knowledge
Appendix D  Illustration representing structural aspects of SDE, with teacher as subject, utilizing activity triangle

Means

Critical reflection, debriefing, cultural-historical activity theory, case studies, co-designing, alternate learning theories, standards

Rules

Respect, collaboration, equity

Community

Researcher, students, school administrative staff

Division of Labor

Teacher and researcher as co-designers, teacher as intellect, teacher as lead in instruction, researcher as lead in retrospective data analysis

Subject

Teacher

Object

Develop student-centered science instructional practice

Exchange

Production Consumption

Distribution

Rules

Teacher

Community

Division of Labor

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## Appendix E  Teacher Planner for List of Standards

### Unit 1: Scientific foundations, measurement (12.5)

<table>
<thead>
<tr>
<th>Standard(s)</th>
<th>Topic</th>
<th>Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>n/a</td>
<td>Lab instruments and safety</td>
<td>1.5</td>
</tr>
<tr>
<td>n/a</td>
<td>Uncertainty</td>
<td>0.5</td>
</tr>
<tr>
<td>n/a</td>
<td>Significant figures</td>
<td>0.5</td>
</tr>
</tbody>
</table>
| H.C.1A.3; H.C.1A.4; H.C.1A.5 | Dimensional analysis:  
1. Metric to metric  
2. Imperial to imperial  
3. Metric to/from imperial | 2 |
<p>| H.C.1A.4 | Graphing | 1 |
| H.C.1A.3 | Accuracy versus precision | 0.5 |
| H.C.1A.3; H.C.1A.4; H.C.1A.7 | Scientific method (review) | 1 |
| H.C.1A.4 | Percent error | 0.5 |
| H.C.1A.1; H.C.1A.3; H.C.1A.5 | Lab: Measurement using lab tools | 1 |
| H.C.1A.6 | Density notes and lab: Density | 1 |
| C-5.6 | Honors lab: Water displacement | 1 |
| | Review | 0.5 |
| | Quiz and test | 1.5 |</p>
<table>
<thead>
<tr>
<th>Standard(s)</th>
<th>Topic</th>
<th>Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>H.C.4A.1</td>
<td>States of matter (solid, liquid, gas, plasma)</td>
<td>2</td>
</tr>
<tr>
<td>H.C.4A.2</td>
<td>Classification of matter</td>
<td>0.5</td>
</tr>
<tr>
<td>5.P.2B</td>
<td>Characteristics of physical and chemical properties/changes</td>
<td>0.5</td>
</tr>
<tr>
<td>7.P.2B.4</td>
<td>Heating curve</td>
<td>2</td>
</tr>
<tr>
<td>Demo:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Dry ice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Diaper powder and effects with salt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Acid-base phenolphthalein color change of sodium in water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Dry ice with soap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H.C.7A.3</td>
<td>Lab: Rates of Reaction</td>
<td>1</td>
</tr>
<tr>
<td>1. Temperature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Catalyst</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Concentration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Particle size through surface: volume ratio</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H.C.3A.6</td>
<td>Lab: Slime (polyvinyl alcohol)</td>
<td>1</td>
</tr>
<tr>
<td>Review</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Quiz and test</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>Standard(s)</td>
<td>Topic</td>
<td>Day</td>
</tr>
<tr>
<td>--------------</td>
<td>------------------------------------------------------------------------</td>
<td>-----</td>
</tr>
<tr>
<td></td>
<td>Activity: DAQRI 4D elements</td>
<td>1</td>
</tr>
<tr>
<td>H.C.2A.1</td>
<td>Atomic structures (proton, neutron, electron locations)</td>
<td>2</td>
</tr>
<tr>
<td>7.P.2A.2</td>
<td>Periodic table notes</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>- Include demos of Group 1 and Group 2</td>
<td></td>
</tr>
<tr>
<td>C-2.3</td>
<td>Periodic trends and periodicity</td>
<td>1</td>
</tr>
<tr>
<td>H.C.2A.2</td>
<td>Modeling through calcium for CP:</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1. Bohr model w/ and w/o ions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Electron dot w/ and w/o ions (skip transition metals)</td>
<td></td>
</tr>
<tr>
<td>C-2.3</td>
<td>Isotopes</td>
<td>1</td>
</tr>
<tr>
<td>H.C.2B.1;</td>
<td>Radioactive series: Alpha, beta, gamma</td>
<td>1</td>
</tr>
<tr>
<td>H.C.2B.2</td>
<td>Half-life</td>
<td>1</td>
</tr>
<tr>
<td>H.C.2B.2</td>
<td>Nuclear fission and fusion</td>
<td>0.5</td>
</tr>
<tr>
<td>H.C.2B.1</td>
<td>Honors: Nuclear medicine</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Review</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Quiz and test</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Unit 3: Atomic structure and periodicity, nuclear chemistry with real-world applications (14)
**Unit 4: Chemical formulas and Types I, II, and III (with polyatomic ions) (9.5)**

<table>
<thead>
<tr>
<th>Standard(s)</th>
<th>Topic</th>
<th>Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>H.C.3A.1;</td>
<td>Types I and II w/ and w/o Polyatomic Ions (Ionic)</td>
<td>3</td>
</tr>
<tr>
<td>H.C.3A.2;</td>
<td>1. Name formulas</td>
<td></td>
</tr>
<tr>
<td>H.C.3A.3</td>
<td>2. Write formulas</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Lewis structure showing bonds</td>
<td></td>
</tr>
<tr>
<td>H.C.3A.1;</td>
<td>Type III (Covalent)</td>
<td>2</td>
</tr>
<tr>
<td>H.C.3A.2;</td>
<td>1. Name formulas</td>
<td></td>
</tr>
<tr>
<td>H.C.3A.3</td>
<td>2. Write formulas</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Lewis structure showing bonds</td>
<td></td>
</tr>
<tr>
<td>C-6.7</td>
<td>Naming acids and bases</td>
<td>1</td>
</tr>
<tr>
<td>H.C.1A.2;</td>
<td>Lab: Flame test</td>
<td>1</td>
</tr>
<tr>
<td>H.C.2A.3</td>
<td>Review</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Quiz and test</td>
<td>1.5</td>
</tr>
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</table>

**End of Quarter 1/ Quarter 3**
### Unit 5: Chemical reactions, balancing, enthalpy with emphasis on exo/endo reactions

(Parts 1 (14))

<table>
<thead>
<tr>
<th>Standard(s)</th>
<th>Topic</th>
<th>Day</th>
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<tbody>
<tr>
<td>H.C.6A.1</td>
<td>Identifying the 5 types of reactions</td>
<td>2</td>
</tr>
<tr>
<td>H.C.6A.4</td>
<td>Balance chemical equations</td>
<td>3</td>
</tr>
<tr>
<td>H.C.6A.1</td>
<td>Write word equations with appropriate symbols</td>
<td>2</td>
</tr>
<tr>
<td>H.C.5A.4</td>
<td>Acid-base emphasis</td>
<td>1</td>
</tr>
<tr>
<td>H.C.6A.3</td>
<td>Law of conservation of matter</td>
<td>1</td>
</tr>
<tr>
<td>H.C.5A.4;</td>
<td>Lab: Conservation of matter (acetic acid and sodium</td>
<td>1</td>
</tr>
<tr>
<td>H.C.6A.3</td>
<td>bicarbonate)</td>
<td></td>
</tr>
<tr>
<td>H.C.5A.4</td>
<td>Honors lab: Titration acid-base</td>
<td>2</td>
</tr>
<tr>
<td>Review</td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Quiz and test</td>
<td></td>
<td>1.5</td>
</tr>
</tbody>
</table>
**Unit 5**: Chemical reactions, balancing, enthalpy with emphasis on exo/endo reactions

(Parts 2 (11))

<table>
<thead>
<tr>
<th>Standard(s)</th>
<th>Topic</th>
<th>Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>H.C.6A.1</td>
<td>Predicting products and rules</td>
<td>3</td>
</tr>
<tr>
<td>H.C.6A.1;</td>
<td>Activity series (single replacement) and</td>
<td>1</td>
</tr>
<tr>
<td>C-6.12</td>
<td>solubility rules (double replacement)</td>
<td></td>
</tr>
<tr>
<td>H.C.7A.1</td>
<td>Thermodynamics (endo and exo)</td>
<td>1</td>
</tr>
<tr>
<td>H.C.6A.1</td>
<td>Lab/demo: Types of reactions</td>
<td>varies (3)</td>
</tr>
<tr>
<td>H.C.6A.1</td>
<td>1. Synthesis: Mg ribbon + O₂ gas</td>
<td></td>
</tr>
<tr>
<td>H.C.6A.1</td>
<td>2. Decomposition:</td>
<td></td>
</tr>
<tr>
<td>C-6.12</td>
<td>H₂O₂ + (MnO₂ catalyst) → H₂O + O₂</td>
<td></td>
</tr>
<tr>
<td>H.C.7A.2</td>
<td>3. Single replacement: Al + CuCl₂</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Double replacement: (12 types of DR reactions lab)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Combustion: Whoosh bottle (demo)</td>
<td></td>
</tr>
<tr>
<td>H.C.7A.1;</td>
<td>Lab: Endo- and exothermic reactions</td>
<td>1</td>
</tr>
<tr>
<td>H.C.7A.4</td>
<td>Review</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Quiz and test</td>
<td>1.5</td>
</tr>
</tbody>
</table>

151
<p>| <strong>Unit 6</strong>: Stoichiometry with concept of limiting reactant (20 CP, 22 H) |
|-------------------|---------------------------------|-----|
| H.C.6A.3          | Concept of the mole and Avogadro's number | 1.5 |
| H.C.6A.3          | Molar mass (conservation of molecular weight) | 1.5 |
| H.C.6A.3; H.C.6A.4| Stoichiometry:                   | 4   |
|                   | 1. A to A (particles, mole, mass, volume) 1 and 2 steps |     |
|                   | 2. A to B (particles, mole, mass, volume) 1, 2, and 3 steps |     |
| H.C.1A.4          | Percent error                    | 0.5 |
| H.C.3A.7          | Percent composition              | 0.5 |
| H.C.6A.3          | Percent yield                    | 1   |
| H.C.5A.3          | Molarity and serial dilutions    | 2   |
| H.C.6A.4          | Honors: Limiting reactant        | 2   |
| H.C.5A.3          | Lab: Molarity of NaCl            | 1   |
| H.C.3A.7          | Lab: Sugar in gum                | 2   |
| H.C.6A.3; H.C.6A.4| Lab: Kool-Aid drink              | 1   |
| H.C.6A.4          | Lab: Air bag stoichiometry       | 2   |
| H.C.6A.3; H.C.6A.4| Honors Lab: Mini-rocket stoichiometry | 2  |
|                   | Review                           | 0.5 |
|                   | Quiz and test                    | 1.5 |</p>
<table>
<thead>
<tr>
<th>Unit 7: Organic chemistry (Chemistry 2 Topics)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H.C.3A.5; C-3.7</td>
</tr>
<tr>
<td>H.C.3A.3</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Standards not directly addressed in Chemistry 1:

H.C.1A.8: Lab Report
H.C.2B.4: $E = mc^2$ mass defect and nuclear strong force
H.C.3A.3: VSEPR
H.C.3A.4: Ionic vs. covalent in polar and nonpolar bonds
H.C.3A.5: Organic naming
H.C.4A.3: Kinetic molecular theory, $PV = nRT$, temperature in Kelvin
H.C.5A.1: Dissociation, dispersion, and ionization of $H_2O$
H.C.5A.2: Rates of reaction lab
H.C.6A.2: Le Châteliers equilibrium principle
# Appendix F  Lesson Plan Template 2018-2019

**Teacher:**  
**Week:** 8/20/18-8/24/18  
**Class:** Chemistry 1 CP

**Unit Title:** Scientific Foundations, Measurement  
**Unit Learning Target:** By the end of the unit, I will be able to adequately assess and model safe laboratory procedures and obtain quantitative and qualitative results from different scientific scenarios from labs and theoretical problems.

<table>
<thead>
<tr>
<th>Standards</th>
<th>Learning Target</th>
<th>Activating Strategy</th>
<th>Instructional Delivery</th>
<th>Closing/Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>adhere to the classroom rules as evidenced by my behavior the rest of the semester.</td>
<td>Building classroom trust by having Mr. Chen share who he is to the students.</td>
<td>State classroom procedures and academic expectations, with time at the end of the class reserved for questions.</td>
<td>Student questionnaire and oral assessment of classroom rules</td>
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| Tuesday   | describe safe lab procedures as evidenced by discussing with a partner what to do and what not to do in a science classroom. | Flashcard 3-2-1 (turned in as BR*). | Show safety video, go over syllabus, go over long range plan and research study. | Students describe lab safety rules aloud.  
Safety assessment (take home) |
<table>
<thead>
<tr>
<th>Wednesday</th>
<th>identify the lab equipment and their uses by matching the tools on a formative assessment.</th>
<th>Discuss one’s familiarity with lab equipment from previous science courses with a partner.</th>
<th>Recall lab equipment, emphasize tools pertinent to chemistry, use of measuring instruments in a lab setting, lab equipment Bingo.</th>
<th>Exit ticket</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thursday</td>
<td>estimate an instrument’s uncertainty while applying accurate data collection processes by completion of a problem set.</td>
<td>Recall the lab instruments and their uses from the previous day’s lab.</td>
<td>Model how to calculate an instrument’s uncertainty, practice determining uncertainty together, have students determine the uncertainty of the lab instruments, apply knowledge to problems.</td>
<td>Problem set</td>
</tr>
<tr>
<td>Friday</td>
<td>discover my areas of strength and weakness when it comes to chemistry concepts by completion of the pre-test.</td>
<td>Describe the purpose and importance of a pre-test to the students.</td>
<td>Assign pre-test.</td>
<td>Pre-test</td>
</tr>
</tbody>
</table>

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Appendix G  Lesson Plan Template 2018-2019

Teacher: Week: 8/20/18-8/24/18  Class: Chemistry 1 H

**Unit Title:** Scientific Foundations, Measurement

**Unit Learning Target:** By the end of the unit, I will be able to adequately assess and model safe laboratory procedures and obtain quantitative and qualitative results from different scientific scenarios from labs and theoretical problems.

<table>
<thead>
<tr>
<th>Standards</th>
<th>Learning Target</th>
<th>Activating Strategy</th>
<th>Instructional Delivery</th>
<th>Closing/Assessment</th>
</tr>
</thead>
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<td>Pre-test</td>
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</table>
Appendix H Teacher Plans For Friday Discussions

Friday discussion: Genetic engineering

Look into the following questions. You don’t have to answer all questions if you cover one question in a lot of detail. You don’t have to cover a question in much detail if you look into all of the questions. The more you look into the question(s), the more comfortable you’ll be and more likely you will participate in the class discussion.

MAKE SURE TO HAVE A RESPONSE FOR QUESTION 5 OR 6 IN ADDITION TO THE OTHER QUESTIONS YOU CHOOSE.

Questions to guide our conversation:
1. What: is genetic engineering?
2. Since when: has genetic engineering been around?
3. Why: is genetic engineering growing now?
4. What: is the FDA’s stance on genetic engineering? (Hint: Who is the FDA?)
   * 5. How: does biochemistry come into play with genetic engineering?
6. Other: Who is Spark Therapeutics and what recently was stated in the news relating to this company?
7: Opinion: Should we have the power to genetically engineer some traits? Where do we draw the line?

Submit a word document (or, if on paper, submit a reply saying “In basket”) by the start of the class period on Wednesday.

Due Oct 9, 2017, 8:55 AM

Friday discussion: Cloning 10/5

Look into the following questions. You don’t have to answer all questions if you cover one question in a lot of detail. You don’t have to cover a question in much detail if
you look into all of the questions. The more you look into the question(s), the more
comfortable you’ll be and more likely you will participate in the class discussion.

MAKE SURE TO HAVE A RESPONSE FOR QUESTION 5 OR 6 IN ADDITION
TO THE OTHER QUESTIONS YOU CHOOSE.

Questions to guide our conversation:

1. What: is cloning?

2. Where: is cloning allowed? Are there restrictions or guidelines?

3. When: did the first successful cloning happen? (There might be different “first”
cloning events.)

4. Why: is cloning something that scientists are spending their time looking into it?

* 5. How: does biochemistry come into play with cloning?

* 6. How: does one become a biochemist? How many sciences do you need to take?
List the sciences.

7. Other: What are some of the controversies that surround cloning? Why might
there be sides that support and oppose cloning?

8. Opinion: Do you think this would be beneficial to you/anyone?

Submit a word document (or, if on paper, submit a reply saying “In basket”) by the
start of the class period on Friday.

Due Sep 22, 2017, 8:50 AM

Friday discussion topic: Rising temperatures and city solutions 9/22/17

Look into the following questions. You don’t have to answer all questions if you cover
one question in a lot of detail. You don’t have to cover a question in much detail if
you look into all of the questions. The more you look into the question(s), the more
comfortable you’ll be and more likely you will participate in the class discussion.

Questions to guide our conversation:
1. What: do scientists suggest are some of the reasons for the rise in temperatures?
2. Where: in the world are the temperatures the highest? (Provide cities, countries, regions, etc.)
3. When: do the temperatures seem to be the highest? Lowest? (Provide time of day, seasons, months, etc.)
4. Why: should other parts of the world pay attention to these cities if the temperatures aren’t getting that hot?
5. How: are cities trying to adjust their living situations to coexist with these high temperatures?
6. How: can chemistry help these cities? Are there any chemicals/chemical reactions that could provide cooler temperatures?
7. Other: What are some possible science careers that can look at the (1) effects of the rise in temperatures and/or (2) city planning?
8. Opinion: Do you think the cities are approaching the rise in temperatures appropriately? Are there better ways? Should it be the cities’ responsibility or the individual citizen?

Submit a word document (or, if on paper, submit a reply saying “In basket”) by the start of the class period on Friday.

Friday Discussion Topic for 9/8/17.

Topic: Stem Cell Research

Look into the following questions. You don’t have to answer all questions if you cover one question in a lot of detail. You don’t have to cover a question in much detail if you look into all of the questions. The more you look into the question(s), the more comfortable you’ll be and more likely you will participate in the class discussion.

Questions to guide our conversation:
1. Who: is leading the research with stem cells?

2. What: is the role of chemistry with stem cells? [or] What: are the limitations of stem cells?

3. Where: is stem cell research occurring (hint: think countries, cities)? [or] Where: is stem cell research not occurring?

4. When: are results expected?

5. Why: are there limitations to what is researched? is chemistry important to stem cells?

6. How: can a better understanding of chemistry help improve the field?

7. Other: What are some possible science careers to work with stem cells?

Students: If you’d like some great, brief articles, I have some physical pdf’s. Please ask for them as I can’t share them digitally. Thanks!
Topics are off-limits when there is a date beside it. 1st Block and 4th Block cannot do the same topic on the same day.

<table>
<thead>
<tr>
<th>Topic</th>
<th>1st Block</th>
<th>4th Block</th>
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</thead>
<tbody>
<tr>
<td>Sports (Concussions, Football, Soccer)</td>
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<td>9/1/17</td>
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<tr>
<td>Quantum Mechanics</td>
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<tr>
<td>Medical Advances</td>
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<tr>
<td>Stem Cell Research</td>
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<td>9/8/17</td>
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<tr>
<td>Snake Morphs</td>
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<td>Drones</td>
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<tr>
<td>Astronomy (Eclipse)</td>
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<td>9/1/17</td>
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<td>Public Safety</td>
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<td>3D Printers</td>
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<td>Robotics</td>
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<td>CRISPR</td>
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<td>Nanotechnology</td>
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<td>Cloning</td>
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<td>Prosthetics/ Enhanced Exosuits</td>
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<tr>
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Appendix I  Teacher lesson plan for nuclear energy

iteration 1

Here’s our brief agenda for the week:

1. To plan for the nuclear energy class. We can bring our ideas and finalize a lesson plan at that meeting.

2. Thursday (September 27) will remain our reflection/discussion day. We will meet via Zoom. Our main focus will be socio-cultural perspectives of learning and equity.

3. We need to confirm with the special education teacher if there are no issues sharing IEP and 504 plans with me for the students. I would also need ESOL data.

4. I will attend and record the whole next week of nuclear energy lesson; I can pick up the camera during this week.

If there is anything else, let me know. I am looking forward to our planning and the lesson on nuclear energy!

Nuclear (3 days)

- Nuclear fusion/fission

- Radioactive series: Alpha, beta, gamma

- Nuclear medicine (honors) ??

- Half-life
**Lesson Plan**

**Day 1**

- Nuclear fusion/fission and radioactive series notes

- Ethics of Nuclear Plant
  - Complete research activity: Answer the following:
    * Types of element(s) used as fuel source
    * When did groundbreaking occur (date)?
    * Safety of site (nuclear and domestic)
    * Under the Conserving Resources heading, what is “conserved”?  
    * Nuclear fission/fusion: Briefing notes
  - Read the following article: Article – *50 Years Later, Man-Made Lake X Did Change Lives Around Here – Community Member with Environmental Impact*
    * Is Lake X a natural lake or is it man-made?  
    * What might be some of the environmental impacts of creating a lake?  
    * Yes or No: Did anyone live in the Lake X area before it was flooded?  
    * If so, whom?  
    * Where does X get its name? From what culture? What is mulberry?  
      Have you seen a mulberry tree around where you live?  
    * What is the main purpose of Lake X?  
    * Fukushima
  
* Nuclear Waste and Alternatives - Briefing Notes*
Day 2

- Group Discussion: what were some of the answers they had found (no more than 3-4; students aren’t done yet)

- Ethics of Nuclear Plant

Day 3

- Continue Power Research
  - Half-life notes
  - How long will the nuclear waste decay?

Role Play:

- Task 1:
• Task 2:
  - Nuclear Plant

• Task 3:
  - How would an engineer determine the half-life of uranium
  - Give formula

• Jigsaw
  - Half-Life
  - Fusion
  - Fission
Appendix J  Supporting material for nuclear power plant, iteration 3

J.1 Nuclear Power Plant Hearing

Background: The US Nuclear Regulatory Commission (NRC) was created as an independent agency by Congress in 1974 to ensure the safe use of radioactive materials for beneficial civilian purposes while protecting people and the environment. The NRC regulates commercial nuclear power plants and other uses of nuclear materials, such as in nuclear medicine, through licensing, inspection and enforcement of its requirements.

NRC Meeting Process: Public meetings are important to the NRC to obtain the people’s confidence in carrying out its mission - to protect public health and safety in commercial uses of nuclear energy. They believe involving the people ensures strong and fair regulation of the nuclear industry. These types of meetings provide an opportunity for NRC and the public to work directly together to ensure that the issues and concerns are understood and considered by NRC. This meeting will be held with representatives of the company, scientists, non-government organizations, private citizens or interested parties, or various businesses or industries to fully engage them in discussion and provide a range of views, information, concerns and suggestions.

The NRC is hosting a Town hall meeting and workshops to discuss the license renewal of X Energy in Y State. The public is invited to observe the meeting between the NRC and the applicant, obtain factual information and participate with feedback on the issues and decisions.
Your assignment: Your team represents a particular professional group you occupy in society. Your team will take on the role and the position (for or against the renewal of X energy power plant) given to you by the NRC. You will use research and the information given prepare a report and to deliver a presentation at the Town Hall meeting to help the people at the meeting understand the issues involved. The people will then provide feedback to NRC members present to help decide on renewing the license of the X nuclear reactor.

Agenda:

- Preparation of Report: As part of your assignment, you must complete a report. Your report has two main sections -
  1. Information Sheets
  2. Presentation Outline
- Preparation of Presentation
- Final Presentation, Review and Decision

Teamwork:

To complete your assignment successfully, teamwork is essential. In order to complete all the tasks given to you you must on different kinds of abilities. No one of you has all the abilities, but each of you had some ability that you will need. Listen carefully to one another and make sure all your teammates are participating. Each one of brings a valuable and different ability. You are all important resources.

Resources and references:

J.2 Report Checklist

To determine accuracy and completion of your reports, you must ensure the following statements are true for your report and tick the checkbox to indicate it is complete.

Report Section 1 (Advantages and Disadvantages of Nuclear Chemistry)

☐ Fill in the name of the two main ideas you will discuss - advantages of nuclear chemistry and disadvantages of nuclear chemistry

☐ In the t-chart (table) provided, below the main idea, fill in supporting details - list the many advantages and disadvantages on each side. You must provide at least 4 advantages and 4 disadvantages.

☐ Are all the spaces provided for writing filled-in?

☐ Do the written responses match your own understanding?

☐ Do the written responses match the information provided (Information sheet and articles)?

☐ If your response was YES to all of the above questions (you have checked all three boxes), then report section 1 is accurate and complete.

☐ Completed Report Section 1
Report Section 2 (Presentation Online)

☐ Are all the spaces provided for writing filled-in?

☐ Do the written responses match your own understanding?

☐ Do the written responses match the information provided (Information sheet and articles)?

☐ If your response was YES to all of the above questions (you have checked all three boxes), then report section 2 is accurate and complete.

☐ Completed Report Section 2

☐ REPORT COMPLETED
<table>
<thead>
<tr>
<th>Role: Social Activist</th>
</tr>
</thead>
</table>

**Description:** Social activists work to promote, guide, or impede changes in government or business policies and influence the actions of individuals and groups. They build connections among groups and communities and disseminate information on specific issues to create awareness and influence social change.

Many of society’s problems are related to the chemical systems that make up the environment (or the chemicals that pollute it), medicines and agricultural chemicals that can affect standards of living, and leaders who abuse their own people or their opponents in war. International teams of scientists can act as diplomats among their respective nations, working to communicate their common goals to their fellow citizens and national leaders, or they may do forensics work to detect the use of chemical weapons or monitor environmental treaties. Scientists may also work to improve standards of living in developing nations by helping citizens set up education programs, provide and implement new technologies, and/or create new jobs in areas such as environmental remediation and sustainable agriculture and manufacturing processes.

**Position:** AGAINST (Against nuclear energy as a source of energy. Does not support renewal of license)
Information Required:

Effects of Nuclear Radiation: The effects of radiation depend on the amount and exposure. Massive doses can be deadly. DNA molecules are sensitive to different radioactive rays.

A. Radiation Exposure (Personal Radiation Dose Test) - Measured in rem’s (it is a quantity of radiation that causes change to human tissue).

B. Detecting Radiation: Film badges, Geiger-Muller counters, and scintillation are three common devices used to detect and measure nuclear radiation. International standards allow up to 5 rem’s a year exposure for those who work with and around radioactive material.

C. Applications of Nuclear Radiation: Radioactive Dating, Radioactive Tracers (both medical and agricultural uses), Radiation Therapy (chemotherapy)

Additional Resources: Economics of Nuclear Energy, Brief History of Nuclear Accidents, Internet Research

Report sections:

1. Advantages and Disadvantages of Nuclear Chemistry

2. Presentation Outline
Guiding Questions for Final Presentation:

1. How do we use nuclear medicine (think about radiation therapy, radioactive tracers)?

2. What is the significance of Chernobyl, Three Mile Island and Fukushima for today’s nuclear energy industry?

3. What are the advantages and disadvantages for using nuclear power to generate electricity?

4. How does the cost of nuclear power plants compare to those that use fossil fuel?
Appendix K  Sample lesson plan for guidance on underrepresentation in science

K.1  Learning about Scientists’ Lives

Total Lesson Time (30-40 minutes)

Table of Contents

- Pre-Lesson Homework
- Lesson Plan
- Resources
- Activities
- Teacher Notes
- Examples

Pre-Lesson Homework (5 minutes) Learn about at least one [under-represented] scientist who did their work before 1950, and one working today. You should have something in common with your physicists. Be sure to use several sources in your research, and document your sources. For at least one, write short answers in your own words to the following, to be handed in:

- What search terms did you use? What websites did you use?
  - Google Image Search: “black physicist”
  - Google Image Search: “physicist”

- What was the path that brought each to physics? What inspired/motivated them?
• Were there obstacles they say they overcame in their career path? (You may not find an answer to this. If you look closely but can’t find one, say this.)

• Summarize their research in your own words in a few sentences. Look up anything you don’t understand!

Lesson Plan

1. Setting the Stage (20-25 minutes)
   (a) We are all uncomfortable (especially majority). Why do it anyways?
   (b) Discussion Guide lines. (Let students modify, add.) Why “brave” space?
   (c) Why are we doing this in science?
   (d) Why discuss race and not gender? (or gender and not SES, etc.)
   (e) Students around the country are doing this, and finding it useful

2. Discussion of homework/warmups (20-25 minutes)
   (a) Who did you find?
   (b) What search terms did you use? What does that tell us?
   (c) What are the effects on each group? (i.e., how does being only a “black physicist” affect black physicists? how does being only “just a physicist” affect white physicists’?

3. Wrap up (5 minutes)
   (a) Thank you for trying something new. [Particular shoutouts for risks taken?]
   (b) Interested students may want to read more narratives of URM Scientists below
As you embark on this unit, you should put some significant thought into how you will create a class culture that will allow everyone to embrace discomfort and push toward real engagement with these ideas...here are a few resources we’ve found helpful in our efforts toward this.

- Spreadsheet summarizing student feedback for other teachers doing this lesson
- It’s OK to resist big new ideas—a great epic length comic from the Oatmeal describing how our minds resist new ideas that might be useful for helping students think about how they approach this unit.
- 1-page summary of one of Moses’s class’s feelings about talking about race, friendship
- Brave Spaces vs. Safe Spaces
- A critical response to “brave spaces” (explicit)—a Stanford student challenges the notion of brave spaces that rely on marginalized people to do the educating/work.

Used in Class Discussion

- Google Image Search: “black physicist”
- Google Image Search: “physicist”

Personal Narratives by Scientists from Under-Represented Groups

- Neil de Grasse Tyson’s excellent response on race and science
- “Double Jeopardy”: the experience of female people of color in science
- Chanda Prescod-Weinstein on unique pressures and Neil de Grasse Tyson
- Chanda Prescod-Weinstein interview, “Speaking Truth (and STEM) to Power”
- The awesome (animated) story of Ronald McNair, physicist and astronaut
- HERstory: Women in Physics Tell Their Stories

More Resources for Scientists from Under-Represented Groups

- Neil DeGrasse Tyson’s website NGT on The Colbert Report
Cosmos (hosted by NGT)
NGT on Twitter
Ron Mallett’s website
This American Life, featuring Ron Mallett- Act Two
Teaching Guides: Women and Racial Minorities in Physics (American Institute of Physics)
LGBT Climate in Physics (American Physical Society)
A blog post that is, in a way, critical of this unit and brings an interesting perspective.

Activities
I use Deltas as a sort of classroom currency for when students want to acknowledge having their mind changed.
Silence Breakers, courtesy of DiAngelo and Sensoy, might be useful to help difficult conversations start.
Shakil Choudry believes that difficult conversations must include not only ideas but space for emotions to bring about change. I survey my students about their emotions before and after this unit, and share the results, as a result.

Teacher Notes
Link to Google Slides Presentation of resources for this lesson
Lesson Plan

1. Introduction to under-representation

   (a) Discussion: what data would we need to see whether a group was properly represented in a given field? How would we analyze that data?

   (b) Data showing underrepresentation: Physics, Chemistry, Bio/Med, Engineering.

   (c) Writing: did anything surprise you? how do you feel when you see this?

   (d) Activity: Stand Up #1

2. Generation of Hypotheses

   (a) Writing: what are all reasons that someone might say under-representation exists?

   (b) Sharing hypotheses, writing them on the board

      i. Group them by “external” (the effects of society) and “internal” (the effects of values held by underrepresented community in question)
ii. Give each a unique identifier (‘A,’ ‘B,’ . . .) as you write

iii. Ask a student to type up or photograph results, for sharing

(c) Activity: Stand Up #2

(d) Introduce HW. Each student should choose a hypothesis to explore.

**Homework:** Hypothesis Exploration

3. Debriefing (note that this combines well with Lesson IIB- Meritocracy)

(a) Students write on a whiteboard/paper:

   i. Which hypothesis letter did you explore?

   ii. what’s one piece of information you want to share?

(b) Students look around the room at everyone’s shared information

   i. See Teacher Notes #3 and #4 below)

   ii. Writing: did you see anything that surprised you? Discussion.

   iii. Discussion: did anyone find any that seemed to disprove a stereotype?

      1. Research finds that many stereotypes are not true

      2. **Thinking of ‘counter-stereotypical examples’** can help erode

      3. I sometimes use this as a chance to introduce **stereotype threat**

      4. Interested students can read some of the Resources below

(c) Discussion: what does this tell us about the nature of science culture?

**Resources**

- Graphs and data representing racial underrepresentation in physics (handout)
- Women, Minorities and Persons with Disabilities in Science and Engineering report
- Undergraduate representation in physics (American Physical Society)
Research Exploring Stereotypes

A Handout of Images Used For Discussion
Teacher expectations of students influence outcomes
More on ‘The Pygmalion Effect’

The original research on gender bias and lab resumes
“Gendered language” on ratemyteacher.com
Gender bias in peer assessment in science
Gender bias in physics grading

Racial disparities in drug use vs. prison time
Racial bias in resume reading (summary)
Racial/gender bias in grad school inquiries

Activities

Stand Up Slips: These slips of paper can be distributed for students to mark (anonymously) their beliefs. Slips are then collected, shuffled, and redistributed. Each statement is read, and students stand if there is a check on the slip they were given. This allows students to see what beliefs are present and which are less common in the room without risking too much. I often ask students to summarize what they saw, whether anything surprised them, how this exercise (writing, standing, etc.) felt to them.

Stand Up 1.

Please check each statement that applies. Please be honest.

☐ Before starting this project, I had noticed a proportional lack of black physicists.
☐ I believe that this lack is a problem
I believe that the reason(s) for this lack is/are a problem

I think I could realistically do something that narrows the lack of black physicists

A mistake I’ve made when talking about race is: (please write clearly on the back)

Stand Up 2.

Please check each statement that applies. Please be honest.

I believe the relatively low numbers of physicists who are black is caused by:

☐ some racial difference in aptitude for physics

☐ lack of effective role models for black students interested in physics

☐ among freshmen, a smaller percentage of black students are interested in studying science

☐ discrimination in the physics hiring process against black applicants

A thought I wish I could share with everyone is: (please write clearly on the back)
Teacher Notes

1. For many years, I worried that naming under-representation might cause students who came from those groups to feel more alienated. Research (1, 2) suggests that the opposite is true: discussing under-representation, if done with an emphasis that this is the result of external factors and not a lack of ability by those under-represented groups, helps to strengthen motivation among those students.

![Graph of Physics Identity vs. Under-Representation Discussion]

Figure 3. Interaction of gender and discussion of under-representation in high school physics as predicting physics identity. (Note that the location of the horizontal baseline is arbitrary: we chose to set it to female students who had a high school physics class where under-representation was not discussed.)

2. I think it’s important to frame the hypothesis formation as “what’s something that someone might say” instead of “what’s something you believe.” My goal is to bring everything out for consideration, even the dangerous-feeling ideas, so that toxic ideas can be addressed and put to rest. Framing the question this way allows students to raise things that they might have heard without worrying that they will be shamed. Anonymous submission would also work. If students are avoiding dangerous ideas - like the ideas that certain groups don’t value school as much - I might even add it to the list myself.

3. That said, it’s critically important that toxic ideas be shown immediately and powerfully to be false: raising the possibility that the lack of representation
reflects some flaw in the under-represented group and then allowing that idea to persist is deeply problematic (and scientifically incorrect). Be sure you are ready to address these ideas if they don’t come up; there’s plenty of research out there to support this.

4. 4) In debriefing the students’ research finding, I have learned not to get too far into the weeds of any one statistic but, instead, to focus on the fact that it’s hard to rule many hypotheses in or out (based on one night’s work, at least). My personal goal in exploring these hypotheses is to open a window for students to consider “what if the under-representation told us something about society, instead of those individuals?” (Not to believe it, but to explore it.) Getting too far into any one hypothesis makes that goal harder to reach, though some exploration of their work helps promote discussion and students’ work to be recognized.
Appendix L  Data used by students to analyze and interpret for underrepresentation in science


Figure L.1: Table 6 – 0 US scientists and engineers, by all degree levels, level of highest degree

<table>
<thead>
<tr>
<th>Level of highest degree</th>
<th>All scientists and engineers</th>
<th>Hispanic or Latino(^a)</th>
<th>American Indian or Alaska Native</th>
<th>Asian</th>
<th>Black or African American</th>
<th>White</th>
<th>Other race(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number SE</td>
<td>Number SE</td>
<td>Number SE</td>
<td>Number SE</td>
<td>Number SE</td>
<td>Number SE</td>
<td>Number SE</td>
</tr>
<tr>
<td>All degree levels(^d)</td>
<td>28,950,000 358,000</td>
<td>2,117,000 55,000</td>
<td>81,000 9,000</td>
<td>3,288,000 46,500</td>
<td>1,826,000 41,000</td>
<td>21,102,000 285,500</td>
<td>536,000 24,000</td>
</tr>
<tr>
<td>Bachelor's</td>
<td>16,650,000 249,500</td>
<td>1,359,000 45,000</td>
<td>53,000 8,000</td>
<td>1,696,000 40,500</td>
<td>1,082,000 31,500</td>
<td>12,128,000 195,500</td>
<td>332,000 19,000</td>
</tr>
<tr>
<td>Master's</td>
<td>8,551,000 121,000</td>
<td>525,000 21,000</td>
<td>25,000 3,500</td>
<td>999,000 21,000</td>
<td>584,000 23,000</td>
<td>6,287,000 104,500</td>
<td>136,000 8,000</td>
</tr>
<tr>
<td>Doctorate</td>
<td>1,360,000 18,000</td>
<td>58,000 4,000</td>
<td>4,000 1,000</td>
<td>266,000 6,500</td>
<td>58,000 4,000</td>
<td>949,000 13,500</td>
<td>22,000 4,500</td>
</tr>
</tbody>
</table>

Data codes used in these tables: \(^a\) = value < 500. \(^b\) = suppressed to avoid disclosure of confidential information. \(^c\) = suppressed for reliability; coefficient of variation exceeds publication standards.
Abbreviations used in these tables: \(^d\) = science and engineering; SE = standard error.
\(^a\) Hispanic or Latino may be of any race.
\(^b\) American Indian or Alaska Native, Asian, black or African American, and white are single race.
\(^c\) Other race includes Native Hawaiian or Other Pacific Islander and persons reporting more than one race who are not of Hispanic or Latino ethnicity.
\(^d\) Total includes professional degrees not broken out separately.
NOTES: Numbers are rounded to the nearest 1,000. Standard errors for numbers are rounded up to the nearest 500. Detail may not add to total because of rounding. Scientists and engineers are bachelor's and higher degree individuals living in the United States with an S&E or S&E-related degree or occupation. See appendix for additional details on coverage, eligibility, educational field classification, and occupational classification.
Data from survey cycle 2013, as of 24 February 2015.
Appendix M  Student responses

The following sections include the student responses both in the form of some scanned questionnaires as well as a table containing some more feedback.
1. Preferred First Name: [Redacted]

2. Current grade: [Redacted]

3. In a word, describe school: [Redacted]

4. State one positive thing about yourself: [Redacted]

5. Write one word that describes you as a person: [Redacted]

6. Who is the best teacher you ever had? Why?: [Redacted]

7. What do you expect to get out of this course? Be specific.: Learn Chemistry

8. What do I need to know about yourself so you can succeed in this class?: I'm a good learner.

9. What do you want to have accomplished by the time you graduate?: Earn a Scholarship

10. State your goal(s) after high school: Go to College

11. State any and all responsibilities outside of school (before and after school – examples: Work at... play... take care of siblings by cooking... etc.): [Redacted]

12. Do you think you are smart? Why or why not?: I'm pretty smart. My grades last year were good.

13. What is one thing you would really like to know about [Redacted]? (Be original, because I will eventually answer everybody's questions!): [Redacted]

Cited from: https://goo.gl/3w4jAT
1. Preferred First Name: [Name]
2. Current grade: [Grade]
3. In a word, describe school: [Boring]
4. State one positive thing about yourself: [Funny]
5. Write one word that describes you as a person: [Athletic]
6. Who is the best teacher you ever had? Why? [Teacher], because she was nice and a good teacher.
7. What do you expect to get out of this course? Be specific. [A credit towards graduation]
8. What do I need to know about yourself so you can succeed in this class? [I am a visual learner.]
9. What do you want to have accomplished by the time you graduate? [All my credits and some college credits.]
10. State your goal(s) after high school: [Go to a 4 year college.]
11. State any and all responsibilities outside of school (before and after school – examples: Work at…, play…, take care of siblings by cooking…etc.). [Volleyball, Basketball.]
12. Do you think you are smart? Why or why not? [Yes, because I have honors classes.]
13. What is one thing you would really like to know about [Teacher]? (Be original, because I will eventually answer everybody's questions!) [Where did you go to school?]

Cited from: https://gojoo gli5awDAT
1. Preferred First Name: [Redacted]
2. Current grade: 10th
3. In a word, describe school: Learning
4. State one positive thing about yourself: Genuine
5. Write one word that describes you as a person: Funny
6. Who is the best teacher you ever had? Why? She’s a fun caring teacher.
7. What do you expect to get out of this course? Be specific: To learn the stuff and to get a good grade.
8. What do I need to know about yourself so you can succeed in this class: I am a visual learner.
9. What do you want to have accomplished by the time you graduate: To get the best grades I can and achieve a GPA of 4.6.
10. State your goal(s) after high school: Graduate with honors.
11. State any and all responsibilities outside of school (before and after school – examples: Work at... play... take care of siblings by cooking... etc.):
   - Play: Cross Country
   - Work: On cut and Son Chores: Drove the house
12. Do you think you are smart? Why or why not: I think I am average. People say I am but sometimes I don’t get stuff.
13. What is one thing you would really like to know about...? (Be original, because I will eventually answer everybody’s questions)
   Are you hispanic, if so what are you mixed with?
1. Preferred First Name: [redacted]
2. Current grade: 10th
3. In a word, describe school: Challenger
4. State one positive thing about yourself: I am open-minded
5. Write one word that describes you as a person: Honesty
6. Who is the best teacher you ever had? Why? Mr. Lloyd, he didn't just teach us what was in the book, he let us discuss things that actually helped us learn.
7. What do you expect to get out of this course? Be specific: Knowledge about chemistry.
8. What do I need to know about yourself so you can succeed in this class: Explain things simply so I can understand the lesson.
9. What do you want to have accomplished by the time you graduate: Diploma, Driver's License
10. State your goal(s) after high school: Go to college – Go to law school, become a lawyer, judge, when Supreme Court says ‘Don’t hang people’
11. State any and all responsibilities outside of school (before and after school – examples: Work at..., play..., take care of siblings by cooking..., etc.):
12. Do you think you are smart? Why or why not? Yes, well according to educational standards, I am passing all my classes. So I must be a genius.
13. What is one thing you would really like to know about? (Be original, because I will eventually answer everybody’s questions) Why out of all subjects did you choose chemistry? [redacted]
**Student’s feedback on nuclear energy lesson (table)**

<table>
<thead>
<tr>
<th>State one big idea about nuclear chemistry and nuclear energy you learned?</th>
</tr>
</thead>
<tbody>
<tr>
<td>That nuclear power plants effects/destroys the environment.</td>
</tr>
<tr>
<td>I learned the difference between nuclear fission and nuclear fusion</td>
</tr>
<tr>
<td>The emissions of green house gases and therefore the contribution of nuclear power plants to global warming is relatively little.</td>
</tr>
<tr>
<td>the difference between fusion and fission</td>
</tr>
<tr>
<td>That it affects many minorities</td>
</tr>
<tr>
<td>Nuclear energy is a risky but worthy industry nuclear chemistry is the study of nuclear reactions.</td>
</tr>
<tr>
<td>Half life!</td>
</tr>
<tr>
<td>Learned that nuclear fission was the splitting of the atom to create more energy.</td>
</tr>
<tr>
<td>I learned steps on how to generate electricity in a power plant</td>
</tr>
<tr>
<td>Nuclear energy has two ways to released by fusion and fission. Fusion is together and fission is separated.</td>
</tr>
<tr>
<td>One thing I learnt was that nuclear energy is very efficient but also very dangerous</td>
</tr>
<tr>
<td>I learned that half life is a way that you can figure out how long it takes for an element to decay and I learned that nuclear energy is better to use for the environment but it isn’t as safe.</td>
</tr>
<tr>
<td>I learned about all of the radiation that nuclear energy causes</td>
</tr>
<tr>
<td>half live and energy save up a lot of money</td>
</tr>
<tr>
<td>Half-life</td>
</tr>
<tr>
<td>Half lives</td>
</tr>
</tbody>
</table>
Half-lives is the time that it takes for half of an atom to decay.

Nuclear fission and Nuclear fusion

It’s not as dangerous as everyone says but it still CAN be dangerous.

I learned about Half-life, which is the idea that half of a group of atoms decay after a certain time frame.

Nuclear energy can affect the water which effects plant and animal life surrounding the power plant.

There are different rays other than just gamma rays.

That is still around that it is actually extremely dangerous.

Nuclear chemistry doesn’t always use harmful/dangerous materials.

It creates big amounts of energy that can be used for great cities, or even countries, but it also makes large amounts of waste that can be very harmful for the nature and for us; it can change the environment completely.

It has negative impacts on many things and goes way back in time from now.

Well, I suppose I learned that nuclear reactors use steam to power turbines. That was fascinating.

I did not know that Uranium miners could be exposed to 50 times safe radiation levels.

Nuclear chemistry can have some negative affects and also positive affects.

I learned about the dangers of using nuclear reactors.

That an advantage is the US saves money from it.

That nuclear energy is environmental friendly.

that’s where we get our energy.
Nuclear energy cause less greenhouse emissions

I didn’t know it provided electricity

They both can be beneficial.

It expensive and could cost us a lot

I learned that is really expensive and it can also be really dangerous.

The supplies for nuclear energy last for a long time. Nuclear energy is the safest and most dangerous energy in the world.

Doesn’t actually harm the air and can cause many accidents

It makes most the world’s energy

It is really expensive and it could be really dangerous

We waste a lot of energy around the world which is bad for the environment. Yet we still need it for light, gas, etc.

Nuclear chemistry deal with radioactive and nuclear energy releases fission and fusion.

without it we wouldn’t have use of the things we have today.

nuclear chemistry- dealing with nuclear properties// nuclear energy-dealing the steam that come out from the tube

nuclear fusion and nuclear fission

I learned it’s really expensive and they could also be really dangerous.

Nuclear energy can be good and bad at the same time

that you had to have a license
**What did you learn about yourself and your skills or abilities?** (Think about skills you have and used to successfully complete your assignment, the skills you observed from your peers, new skills you learned, your career interests etc.)

That i can’t let my anxiety or fear or speaking in front of the class effect my grade or participation.

I learned that I can present.

i like making slides presentations and working in groups and that nuclear energy sometimes hurt animals(thats bad because i want to be a veterinarian and i have to help those types of problems)

creating google slides

it made me think more

I learned that i need to stay more focused and work harder ro complete the task efficently

I tend to be a bit bossy when it comes to groupwork, I just like being in charge, you know?

I’m not very good at presenting info, and I don’t need to read slides word for word.

I learned new skills such as how to research things carefully and also how to analyze information and involve it in my work.

To talk over about what we are doing and if someone don’t understand then we would talk it over.

I learnt that working in a group might not always be the solution to getting work done but it helps to limit the amount of work you have to do.

I learned that I can present projects better than I used to do in the past.
I learned that I don’t want to be a scientist and also that I work pretty good with partners when we all have an assigned task.

I am good with presentation and doing a lot of edit on it.

I like working with other people because you get their feedback.

I liked working with people

Working with others

I like the science part of chemistry, hate the math part

I think I’m a good leader and I believe I’m good at coming up with ideas that will help presenting be more interesting.

I suck at remembering to do things, as I forgot to finish the handout sheet till 11:30 at night on the day before the presentation. When it comes to skills and abilities, I feel like I know myself pretty well, it was expected.

I’m a good organizer

I learned that I am a little impatient, and like things to go my way even though it can’t always be that way. I also learned to let others do things the way they would like to instead of giving very strict instruction.

I didn’t learn anything about myself or my skills

I learned to work with the partners i’m given even if you don’t really want to just make the best of it.

I had difficulty processing all of the information in the beginning.

I learned that I am a good leader, I can discuss opinions with my partners and formulate an argument. I am good at making the presentations, but kind of bad presenting them.
I learned that I worked well with my group because we all had different ideas and opinions which really made me think in different ways.

I learned that I’m not the best at catching up on projects so I need to work on that.

My research and data analysis has improved in my opinion.

Some of the skills that I have was to be able to create a presentable power point or slides. It helped a lot because of the format me and my partners used for the information gathered.

as a group we have learned to work together and put everything together around our weaknesses and strengths

I think I was able to do the project faster since it was easy to understand.

i am good at pulling information from the text and comprehending what the article is saying.

its not hard to find answer

I learned that i am a good leader for a small group and i listened to every idea said and incorporated into the project

i learned that i work well with others

I learned i Can work on something i didnt know about before.

I learned that I can finish something in a short amount of time.

I learned to communicate with others more than I usually do.

I can things done and assist my team mates to finish things quickly.

I learned that I tend to work alone to get my work finished more but working in a groups makes me feel more involved into the project.

I learned my research skills can be helpful when doing these projects

I learned how to present better in front of a class
I learned that working with other people and communicating together is a great way to finish the assignment and getting a good grade on it instead of getting distracted easily.

<table>
<thead>
<tr>
<th>I was able to help more to my partner because I knew more and more ideas</th>
</tr>
</thead>
<tbody>
<tr>
<td>I get easily distracted</td>
</tr>
<tr>
<td>While I give out ideas people like it and they get more information from it</td>
</tr>
<tr>
<td>That I can work with people even if we aren’t good friends</td>
</tr>
<tr>
<td>Well I learn that chemistry class it’s interesting because there are many things that I didn’t know exist.</td>
</tr>
<tr>
<td>I need to learn better communication</td>
</tr>
<tr>
<td>That I can do things if I stay focused</td>
</tr>
</tbody>
</table>

197
**What did you like best about this lesson activity? Why?**

<table>
<thead>
<tr>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>That we were able to research and use the information we found instead of it all being given to us. Because I feel it helped me learn better what I was actually doing instead of just copying stuff from a website given.</td>
</tr>
<tr>
<td>I liked that we got to work with people and got to do something different.</td>
</tr>
<tr>
<td>Creating the slide presentation.</td>
</tr>
<tr>
<td>Working in groups because it was fun</td>
</tr>
<tr>
<td>The reading</td>
</tr>
<tr>
<td>I liked looking at the chemical accidents.</td>
</tr>
<tr>
<td>Getting to pick our groups, to amplify our positive teamwork related qualities</td>
</tr>
<tr>
<td>The ability to work in groups and work on your own time because it created independence among students.</td>
</tr>
<tr>
<td>I liked that we did something different and allowed us to work and learn on our own.</td>
</tr>
<tr>
<td>Working with the people I wanted to be with.</td>
</tr>
<tr>
<td>Working in a group because working by myself can be boring sometimes</td>
</tr>
<tr>
<td>We got to do thorough research on the topic that was assigned to us.  Adam Wrights</td>
</tr>
<tr>
<td>I liked playing the part of a nuclear scientist so I could explain what I had learned as if I was really an expert</td>
</tr>
<tr>
<td>We learned the pros and cons of Duke Energy</td>
</tr>
<tr>
<td>I liked that you got to pick your own groups.</td>
</tr>
<tr>
<td>I liked working with people.</td>
</tr>
<tr>
<td>Having to teach the topic because I had to master the information. Adam Wrights</td>
</tr>
<tr>
<td>Making the slides because it was easy</td>
</tr>
</tbody>
</table>
I liked creating the slides and the idea of the project. I did enjoy learning something new.

I enjoyed the challenge of it, and the fact that we got to learn the subject ourselves.

We got to focus on something that actually affects us.

I liked that it was interactive and we were able to teach ourselves because sometimes I don’t really understand things unless I do it myself.

The new information I learned

I liked being put in the role of the real life scientist because it gave you a feel of what they do.

I liked that it was set up like a town meeting where everyone was able to express their opinion.

I liked the topic that we were working on because for me it was interesting and it is related to nowadays.

We could see how these meetings actually are held and got to learn the information in a different, hands on way.

I really enjoyed working together with my group because of how cooperative, and on task my group remembers were.

It allowed me to see the other side of the argument on nuclear energy.

The best thing about the activity was who each group was able to present important information about the situation we were debating about. It gave information about why they believed about nuclear energy.

I liked presenting. It was fun and engaging

I liked my group and being able to learn about nuclear chemistry.

we got to work in groups, and we got to create our own presentation. group activity
<table>
<thead>
<tr>
<th>Working with partners because we got so much work done in 3 days i like working in groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>We learned some about nuclear energy with out a teacher.</td>
</tr>
<tr>
<td>My favorite thing about this lesson was working with a group</td>
</tr>
<tr>
<td>I like the way we got to learn different point of views and why is good and bad.</td>
</tr>
<tr>
<td>We all got to work in a group and mange to finish.</td>
</tr>
<tr>
<td>we get to present together as a group rather than presenting as an individual in front of the whole class</td>
</tr>
<tr>
<td>We got to work in groups.</td>
</tr>
<tr>
<td>I liked it how we could worked in groups it made me easily understand the lesson better.</td>
</tr>
<tr>
<td>We worked together as a team</td>
</tr>
<tr>
<td>That we had to answer questions in each group because that means we had to pay attentions to the presentation</td>
</tr>
<tr>
<td>the presentation part, we got to talk infront of the class</td>
</tr>
<tr>
<td>we worked together on it</td>
</tr>
<tr>
<td>we got to work in partners because science is one of my harder subjects so i like extra help.</td>
</tr>
<tr>
<td>I like about this lesson activity this to work in a group and have my partners got differents ideas.</td>
</tr>
<tr>
<td>This lesson was very different , it taught me alot about things i have never heard of that we could find our own informations with hearing the teacher talk all day</td>
</tr>
<tr>
<td>What would you change about this lesson activity? Why?</td>
</tr>
<tr>
<td>------------------------------------------------------</td>
</tr>
<tr>
<td>Letting us choose if we wanted to be for or against the topic at hand.</td>
</tr>
<tr>
<td>I would like to learn the material first before we have to just go and pretend like we are experts on something we know nothing about.</td>
</tr>
<tr>
<td>Explaining it more.</td>
</tr>
<tr>
<td>what we did the project of because nobody knew what we were learning about nothing</td>
</tr>
<tr>
<td>Do a short study on the topic before we are supposed to do a project on it.</td>
</tr>
<tr>
<td>Actually knowing what the topic was beforehand. Like...on atoms, since we’ve already done our atom unit.</td>
</tr>
<tr>
<td>Definitely give a brief summary of the lesson before we do it to further knowledge of the topics</td>
</tr>
<tr>
<td>It was a little confusing at first but it was easy after that.</td>
</tr>
<tr>
<td>Maybe have a background infor. about the project we were about to do.</td>
</tr>
<tr>
<td>The amount of time we had because I feel like my group could have done better with a little bit more time</td>
</tr>
<tr>
<td>I would change how we learned this because I was very confused on some of the things that we had to do.</td>
</tr>
<tr>
<td>I would the fact that we didn’t really learn or have an introduction before the project learn sum of it before we did project</td>
</tr>
<tr>
<td>More information</td>
</tr>
<tr>
<td>More time to do more research about the topic</td>
</tr>
<tr>
<td>A topic id have more insight about.</td>
</tr>
</tbody>
</table>
Gaining information and learning more about the other’s subjects. Though I did learn a lot, some groups made it where I couldn’t understand them or what they were presenting.

<table>
<thead>
<tr>
<th>I would give 8 minutes instead of 5 minutes, as the 5 minute time frame is a bit too small for the interactive sheet we were required to hand out.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>amount of time we could work on each part</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1 day for research, 1 day for slides, 1 day for presenting)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>I would give the students more time to complete the project because then more research could be done and they would learn a bit more.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>I wouldn’t change nothing</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>I would want more resources.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>I didn’t like how the information was set up, I feel like it would have been better if each group was sent their info through classroom instead of a bunch of different folders in google drive.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>I would create a debate between the groups that were against it and the ones that were for it. The students would discuss about their ideas with others and would have to support their argument to see which group win.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>I would change the way it was set up. I felt like the directions were confusing and took some of use a while to understand the task. I also felt like we could have been given more time and should have learned a little information about it before we jumped into it.</th>
</tr>
</thead>
</table>
I feel like the activity was very confusing, especially for me because I wasn’t here the day it was explained. In addition to that, I don’t believe the project should have been so complex because it confused me as to what was going on. I also didn’t enjoy using one resource, and I didn’t like how we were supposed to make our power point. Although it’s my personal opinion on the subject, but I feel like there should be a little more freedom to accessing information and how to create slides.

As much as I want to complain about the fact that I did not like the project because I had to argue against one of my passions, I enjoyed the chance at another point of view. I liked the fact that I had the chance to see the other side.

The amount of time given to present would be something that could vary depending on the activity. Such as the one we did, the limit was 5 minutes to present which was possible for some groups. Including with the due date of the assignment there could have been either more time in order to gather more information.

The time limit. It was a little difficult to try and understand and put the info together with the time that we had.

Probably the time and more resources.

maybe give us some more articles because some of us didn’t have much information to go off of.

let us pick choices

I would change the amount of time given because if we had more time we could have had a really detailed project

i would allow us to pick our side of the debate

i Would only make it longer.

nothing
<table>
<thead>
<tr>
<th>I wouldn’t change a thing, I think it was a perfect project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nothing at all.</td>
</tr>
<tr>
<td>To let our group choose if we would be Against or For</td>
</tr>
<tr>
<td>We have more time to present our project</td>
</tr>
<tr>
<td>Give us more time to present, people could be taking notes and it takes u</td>
</tr>
<tr>
<td>I wouldn’t change anything about this activity because everything just came together as planned.</td>
</tr>
<tr>
<td>That we don’t have to present because I people might be really shy to go up and present nothing</td>
</tr>
<tr>
<td>the topic something that we like so we could learn more about it</td>
</tr>
<tr>
<td>make it the presentation a little longer so you can put more information in it.</td>
</tr>
<tr>
<td>Nothing because all was right.</td>
</tr>
<tr>
<td>I would have a better engagement into learning more about it</td>
</tr>
<tr>
<td>more time</td>
</tr>
</tbody>
</table>
Appendix N  Index of topics and readings for teacher support sessions

<table>
<thead>
<tr>
<th>Weekly Focus of Topics</th>
<th>Readings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to scientific practices</td>
<td>Misconceptions of NOS; Underrepresentation Lesson Plan and Supporting Materials</td>
</tr>
<tr>
<td>Equitable chemistry instruction</td>
<td>Case Study 1 from NGSS Framework</td>
</tr>
<tr>
<td>Equity &amp; Social Justice</td>
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**Future Topics**

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Appendix O  Teacher reading on equity

O.1 Definitions

In education, the term equity refers to the principle of fairness. While it is often used interchangeably with the related principle of equality, equity encompasses a wide variety of educational models, programs, and strategies that may be considered fair, but not necessarily equal. It is has been said that “equity is the process; equality is the outcome,” given that equity—what is fair and just—may not, in the process of educating students, reflect strict equality—what is applied, allocated, or distributed equally.

Inequities occur when biased or unfair policies, programs, practices, or situations contribute to a lack of equality in educational performance, results, and outcomes. For example, certain students or groups of students may attend school, graduate, or enroll in postsecondary education at lower rates, or they may perform comparatively poorly on standardized tests due to a wide variety of factors, including inherent biases or flaws in test designs. [Glossary of Education Reform: https://www.edglossary.org/equity/]

**Equitable learning opportunities** occur when school science (1) explicitly values and respects the experiences that all students bring from their home and community environments, (2) articulates this cultural and linguistic knowledge with disciplinary knowledge, and (3) offers sufficient educational resources to support science learning in all schools and classrooms [Lee and Buxton, 2010].

The term equity has been used in different ways by different communities of researchers and educators. Equity as an expression of socially enlightened self-interest
is reflected in calls to invest in the science and engineering education of underrepresented groups simply because American labor needs can no longer be met by recruiting among the traditional populations. Equity as an expression of social justice is manifested in calls to remedy the injustices visited on entire groups of American society that in the past have been underserved by their schools and have thereby suffered severely limited prospects for high-prestige careers in science and engineering. Other notions of equity are expressed throughout the education literature; all are based on the commonsense idea of fairness—what is inequitable is unfair. Fairness is sometimes considered to mean offering equal opportunity to all. The most commonly used definition of equity, as influenced by the Supreme Court’s Brown v. Board of Education (1954, 1955) and Lau v. Nichols (1974), frames equity in terms of equal treatment of all.[NGSS Lead States, 2013]

Bell [Adams et al., 1997] defines social justice as being a goal and a process. “The goal of social justice education is full and equal participation of all groups in a society that is mutually shaped to meet their needs” [Adams et al., 1997, p. 3], while “the process for attaining the goal of social justice . . . should be democratic and participatory, inclusive and affirming of human agency and human capacities for working collaboratively to create change” (p. 4).

Social justice education does not merely examine difference or diversity but pays careful attention to the systems of power and privilege that give rise to social inequality and encourages students to critically examine oppression on institutional, cultural, and individual levels in search of opportunities for social action in the service of social change. Clearly, this definition goes well beyond the celebration of diversity, the use of dialogue groups in the classroom, or even the existence of democratic
processes regarding class goals and procedures. To be most effective, social justice education requires an examination of systems of power and oppression combined with a prolonged emphasis on social change and student agency in and outside of the classroom [Hackman, 2005].

The call for **socially just pedagogy** is a call to ensure that all youth have equitable opportunities to learn. In many cases, this view seeks to provide equal resources for learning, although the socially just pedagogue cannot always control access to material resources. It also can refer to ensuring that all youth learn conventional or academic literacy practices. Some would argue that this stance, although it equalizes skill and provides opportunities for all to achieve social and economic success [Moses and Cobb, 2001], risks reproducing the status quo in terms of cultural dominance. That is, it risks assimilating all people into a dominant, White mainstream rather than opening spaces for many different cultural practices to coexist and even nurture one another [Moje, 2007].

From a social justice perspective, opportunities to learn must not only provide access to mainstream knowledge and practices but also provide opportunities to question, challenge, and reconstruct knowledge [Ladson-Billings and Tate, 1995]. Social justice pedagogy should, in other words, offer possibilities for transformation, not only of the learner but also of the social and political contexts in which learning and other social action take place [Saunders, 2006]. Social justice pedagogy offers these transformative opportunities for all youth, even those who are privileged under current epistemological, social, and political structures. In other words, social justice pedagogy is not restricted to schools populated by youth of color or youth from low-income communities [Moje, 2007].
References


