ABSTRACT

KUDUMU, MWENDA OLUWATOYIN. The Perceptions and Practices of Informal Science Educators Regarding Culturally Relevant Education in Science Centers. (Under the direction of Drs. K.C. Busch and Soonhye Park).

Despite their promise, systemic inequity issues plague science centers and gaps in educational research limit the available responses to address the problems. As a result, the rapidly changing demographics of the US are a risk to science centers unless they attract and retain more racially and culturally diverse audiences, staff, volunteers, and boards. To help science centers achieve their mission of reaching the broader public, there must be a cultural shift in informal science education (ISE) research and practice. The purpose of this study was to understand what N=22 science center educators from N=15 ISE institutions in the US know about cultural relevancy in informal science contexts and do to apply Culturally Relevant Education (CRE) in science centers. CRE was the theoretical framework for this basic qualitative study and semi-structured interviews were the primary source of data collection. Qualitative Content Analysis and constant comparative method were used to analyze N=788 quotes.

Although research findings are not generalizable across the field of ISE, a synthesis of trends resulted in the following three major findings: (1) Cultural relevancy in informal science education is dependent upon a mutually respectful relationship and shared culture developed between the ISE institution, the audience, and the personnel at the institution. Yet, the connection with the audience is often shallow, the relationship with the institution is usually one-sided, and the sharing of culture is habitually hampered by exotification; (2) The role of cultural relevancy is integral to ISE institutions' achieving their mission of engaging the community by increasing accessibility to science. Still, this role functions like a tool kit, or a road map to reach the goal of cultural relevancy, as opposed to the deeper guiding principle of being inclusive; and (3) The

application of culturally relevant principles includes learning about the audience and co-construct science understanding with them. However, institutional and field-wide systemic issues that alienate the community are barriers to enacting culturally relevant practices in science centers. The findings from this study and resulting major assertions have implications for research and practice in the field of science education in informal settings. An educational framework, modified for ISE contexts, that centers culture has the potential to make intellectual and practical contributions to the field.

The Perceptions and Practices of Informal Science Educators Regarding Culturally Relevant Education in Science Centers

by
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A dissertation submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

Learning and Teaching in STEM

Raleigh, North Carolina
2023

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DEDICATION

To my ancestors, whose science conversations were interrupted by the Maafa.

LIVICATION

For the love of science centers and their ability to spark the Black science renaissance.

BIOGRAPHY

Mwenda was born and raised in San Diego, California. The product of a Pan-Africanist household, she learned about the historic scientific contributions of Black people at an early age. Eager to do her part to champion Black scientific involvement, Mwenda earned a degree in Biology from Stanford University. She went on to serve as a biologist for the National Marine Fisheries Service within the National Oceanic and Atmospheric Administration and as a visiting researcher at the Nigerian Institute for Oceanography and Marine Research. Keen on increasing science engagement in Black communities, Mwenda began coordinating outreach programs for science museums in the California Bay Area. Following this career path, she moved across the United States, eventually working in five different science centers before traveling to Ghana to create the University of Cape Coast Science and Technology Center. After completing the course requirements, her pursuit in Ghana of the Master of Philosophy, Zoology degree in Wild Life Management ended before she could present her thesis. Returning to the United States in 2007 to attend to family matters, Mwenda continued to promote science by providing informal programs for schools, summer camps, and community groups in the Research Triangle area. In the fall of 2017, she resumed her studies; this time focusing on science education, at North Carolina State University where she earned a Master's in 2020 while en route to a Ph.D. Mwenda is interested in popularizing science and technology in Black communities through increasing involvement with informal science education (ISE) institutions. Central to her work is the belief that ISE can be used to tear down barriers, address inequities, and make science accessible to Black audiences.

ACKNOWLEDGMENTS

While the final lap of the Ph.D. marathon feels like a long lonely road, it would be an impossible mountain pass without the people lined the entire way to the finishing tape. The coaches that know the route and point the way, the other runners that commiserate around the arduous journey and the cheerleaders that passed out water and antidotes to keep me going are deserving of thanks. I am eternally grateful to them all. First, it is with great respect and gratitude that I recognize my "coaches," my awesome dissertation chairs: Drs. K.C. Busch and Soonhye Park. Thank you for your gentle but firm hands that guided me through this process. Dr. Busch, as my advisor you are an advocate, ally and at times an accomplice. Thank you for going down the rabbit hole with me and pulling me back to the realities of time and space. Dr. Park, I am tremendously grateful for the opportunity to work with you and to reap the benefits of your qualitative research expertise. I am thankful for the enthusiastic support of my committee members, Dr. Cameron Denson, Dr. Zakiya Leggett, and Dr. Porche' Spence. The advice and guidance you gave me along this journey have been invaluable. I am also grateful for the instruction that I received from other professors in the College of Education, including Drs. Blanchard, Delgado, Jefferies, Jones, Kleiman, Thomson, Townsend, and Wiebe. Participating in your courses has deepened my understanding of learning, teaching, and loving science.

Secondly, I would like to thank the networks of academic scholars that ran this race alongside me, some leading the way and finishing before me, while others are still on their journey. Thank you to the Informal Science Learning Lab (ISLL) crew, Lynn Chesnut, Stephanie Teeter, Katy May, Regina Ayala Chavez, Aparajita Rajwade, Dana Haine, and Melissa Schug, for the collaborative environment that allows us to learn from, and even challenge, one another. Thank you to Drs. Shannan George, Megan Ennes, Katie Green, Cody Smith, Matt Reynolds, Shana McAlexander, and the other Ph.D. graduates from the College of Education, for sharing your stories and offering secrets of the trade—like where to park. Thank you to the members of the Black Graduate Student Association (BGSA) for keeping me connected to school during the isolation of the COVID-19 restrictions. Especially thanks to Elyse Smith and Dr. Iwinosa Idahor for dragging me to that last BGSA meeting before the COVID lockdown. Without you two, I would have missed the love, support, and shenanigans that kept me sane during that difficult time.

And to my cheerleaders, I am grateful for my family and friends who celebrated and supported me along this journey. Thank you to old friends that have known me for decades and new friends like the Starbucks staff. Thank you to my Mommy, Maisha Kudumu, who kept the dream of “Dr. Kudumu” alive and also stepped in to act as my research assistant when I needed help finding email addresses for hundreds of science centers. Thank you to my siblings (including sisters-in-law and brothers-in-law), aunts, cousins, nieces, and nephews. My cheering section was large and loud enough to drown out any uncertainties that popped into my head along the way. I offer special thanks to my children, Menefese, Narga, Yashimabet, and Kidus. Thank you for always expressing how proud you are of me, for getting up early to be my writing partner, for cooking your own dinners, finding your own rides home from school and practice, and for your willingness to put off family fun until A.D. (after dissertation). I am me because of you! Certainly, I must acknowledge my loving husband, Coach Derek Biggs. Thank you for never doubting that all of this was possible, for marrying me in the middle of this doctoral process, never shying away from our blended family math where one plus one equals six, and for providing our children the highest example to live up to.

I must pour libations for three ancestors who made this journey possible. Thank you to my Baba, Walter Kudumu, who drove me in the middle of the night across town, to the lab to collect data during my high school science projects. Thank you to Mr. Thomas Watts, founder of the Elementary Institute of Science, who infused the love of science into inner-city Black children like me. Thank you to Dr. Park Trefts, who broke down barriers by handing me the keys to the lab at Scripps Institute of Oceanography when I was 14 years old and then continued to advise and support me by sending science equipment to my lab in Ghana and writing my letter of recommendation for this Ph.D. program. I hope this accomplishment honors the love and work the three of you put into me.

Finally, special thanks to the science center educators that participated in this study. Thank you for generously volunteering your time and trusting me with your stories. Your love for science is infectious, your commitment to a better world is evident, and your efforts at self-improvement is an example for us all.

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INTRODUCTION

Science centers, despite their growing popularity (Association of Science and Technology Centers [ASTC], 2022), have diversity, equity, and inclusion (DEI) concerns (Garibay & Olson, 2020) that threaten the achievement of their mission (Feinstein & Meshoulam, 2014) and the very utility of their existence (Ash 2022; Dawson, 2019). The cultural atmosphere of science centers closely mirrors the culture and politics of science, which is a reflection of the population in power (Ash & Lombana, 2013; Dawson 2014a). Comparable to science, which often excludes perspectives of minoritized groups (Aikenhead, 1999; Brown et al., 2016), science centers fail to attract culturally diverse communities (Ruffo, 2013). Informal science education (ISE) institutions regularly employ educational learning theories, like constructivism (Ash, 2022), that promote experiential, hands-on learning, but are inadequate to address DEI issues (Collins, 2000; Dancstep & Sindorf, 2018). To address DEI issues in formal science classrooms researchers like Aronson & Laughter (2016), Brown (2017), and Brown et al. (2019) adopt critical educational theories that centered culture. However, there are relatively few research studies addressing cultural barriers to participation in ISE (Rennie, 2014), compared to cultural studies in formal science education (Aronson & Laughter, 2016; Brown et al., 2019).

Statement of the Problem

Science centers are important, yet struggles to diversify their boards, staff, and visitors point to systemic flaws (Garibay & Olson, 2020). They attract over 90 million visitors a year (ASTC, 2022), are popular places for multigenerational free-choice learning (Falk & Dierking, 2013; Ruffo, 2013; Stocklmayer et al., 2010), and play an essential societal role in popularizing science (National Research Council (NRC), 2009). In spite of their promise, issues of inequity and inaccessibility have hindered science museums, planetariums, and technology centers from reaching their full potential (Ash, 2022; Rennie, 2014). Unfortunately, ISE institutions have traditionally attracted a very narrow population: affluent, White Americans with young children (Ruffo, 2013). Science should be accessible to all people regardless of race, gender, or socio-economic status (Rahm, 2004). Many researchers agree that issues of inequity and inaccessibility are systemic to ISE and that science museums and science centers have failed to live up to their charge of reaching the broader public (Dawson, 2014a, 2014b; Feinstein & Meshoulam, 2014).

The failure to diversify threatens to eliminate the need for ISE institutions for without the ability to attract the variety of cultures that make up the general public, they cannot fulfil their role of mediation and interpretation of "official science" (Rennie, 2014. p. 124). Tlili et al. (2006) point out that one of the six ways in which science centers mediate science is by relaying the concept that science is multicultural. However, the AAM (2022), in their current issue of TrendsWatch noted the following:

> Historically, the corps of museum volunteers have skewed towards older adults with the time, inclination, and financial resources that enable them to volunteer. As a result, their demographics typically mirror that of museum personnel (both staff and board)—which is often disproportionately white, well-educated, and relatively well-off. Volunteerism can exacerbate inequality if, as in many museums, it is only accessible to people who are already comparatively privileged. (p. 19)

Additionally, diversity shortages in ISE link directly to diversity shortages in science, technology, engineering, and mathematics (STEM) fields (National Science Board [NSB], 2016). There is growing concern over the shortage of diversity in STEM-related fields and the potential threat this causes to the US' presence in science and technology around the world (NSB, 2016).

Engaging in informal science can influence youths' achievement in formal academic settings (Dorsen et al., 2006), help them uncover their science identity, and increase their science capital (Jones et al., 2020; NRC, 2009). On the other hand, not engaging in science can cause further marginalization of underrepresented communities. According to Dawson (2014b):

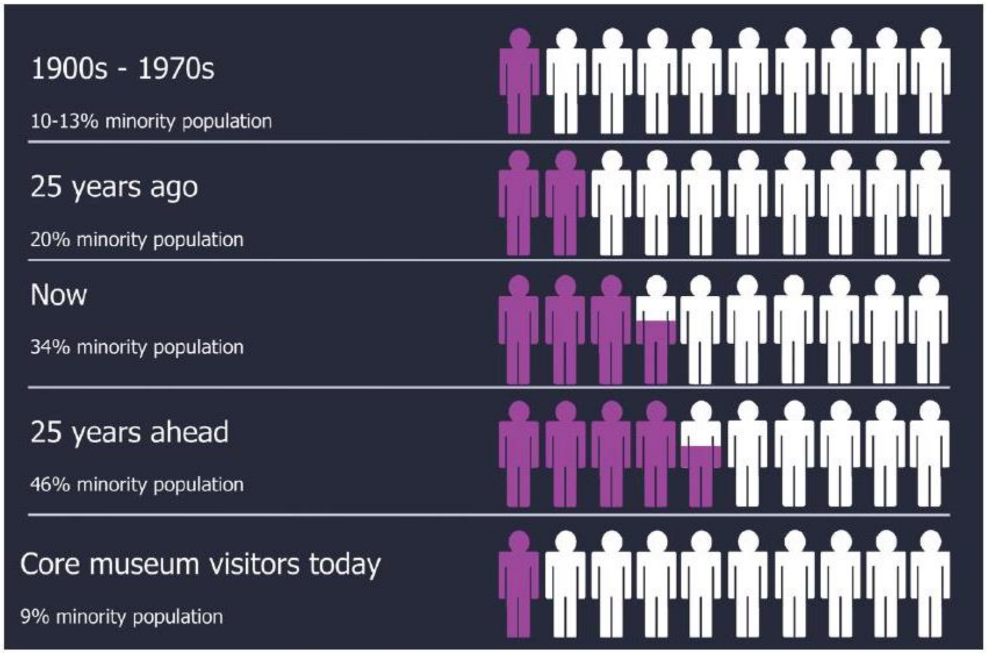
> The role of science is sufficiently central to the different cultural, social, political, educational and economic aspects of contemporary lives that being unable to access opportunities to learn about, participate in, critique or otherwise enjoy science can be understood as a form of marginalization. (p. 220)

Feinstein and Meshoulam (2014) reported that the lack of diversity in ISE institutions could "worsen the inequities of science education." Weiland (2015) noted that non-traditional museum visitors often see visiting ISE institutions as being a "White phenomenon."

The failure to diversify is an existential risk to science centers, as the rapidly changing racial and cultural demographics of the United States (US) may no longer support the sustainability of all White cultural institutions, such as museums (Ash & Lombana, 2013). This is especially true if museum audiences, which have historically been White, wealthy, well-educated Americans, continue to be less diverse than the US population, which is shifting towards increased numbers of people of color (American Alliance of Museums [AAM], 2022). The conflict that museums face is illustrated clearly in a graphic (Figure 1) adapted from The American Alliance of Museum's (AAM's) 2008 report on the future of museums and the diversification of the US population (p. 6). In the graphic, five rows of white and purple stick figures, representing population percentages, can be seen lined up, shoulder-to-shoulder, on the right side of the image. Within a quick glance, prior to digesting the text located on the left side, the reader is aware that the purple figures—which represent the percentage of minority populations—increase from one row to the next, then return to just one on the last row. The first four rows depict the changing racial demographic in the US from the early 1900s projected to the year 2035 as one with increasing proportions of underrepresented people. While the last row represents the contemporary racial makeup of museum visitors, which remains at lower levels of minority representation. Doris Ash, in her recent book, *Reculturing museums: embrace conflict, create change,* defines the contemporary conflict that US museums face as demographic changes linked to insecure funding, and "societal cultural movements, such as decolonizing," (Ash, 2022, p.3).

Figure 1

Demographic Transformation in the United States and the Future of Museums



Note. Reach Advisors produced this figure in 2008 for AAM, using data from the U.S. Census Bureau and responses from 30,000 museum visitors. From *Museums & Society 2034: Trends and*

Potential Futures (Version 1.0, p. 6), by AAM, 2008. Copyright 2008 by American Alliance of Museums.

The changing demographic dilemma accentuates DEI issues that are inherent to the culture of science centers, which closely align with the culture of science. The association of science centers with "White Phenomenon" is a reflection of their core values and practices as cultural institutions established by the population in power (Ash, 2022; Weiland, 2015). When Dawson (2019) asks, "Whose cultures and languages are represented in museums and galleries?" she poses a rhetorical question with her response provided at the beginning of the paragraph: "the ripples of colonialism and globali[z]ation continue to play out" (p. 3). Recognizing that ISE institutions consist of predominantly White people and mirror the culture of the dominant population; Ash and Lombana (2013) describe the shift science museums will have to make to ensure equal access to all communities as *reculturing.* This reculturing shift requires science center educators, board members, administration, volunteers, and visitors to reject the exclusive culture of Western science, to embrace perspectives of non-dominant cultures, and to strive for a culture of equity throughout all levels of the institution (Ash, 2022; Ash & Lombana, 2013).

Despite these concerns, there is a dearth of research available on the cultural barriers to participation in ISE (Ash & Lombana, 2013; Dawson, 2019; McLaughlin & Diamond; 2020). While some ISE researchers have examined changes in museum educators' practices (DeGregoria, 2009; Seig & Bubp, 2008; Tran, 2008), there are only a small number of publications linking sociocultural theories to practices in science centers (Ash & Lombana, 2013). Considering the growing cultural studies in formal STEM education (Aronson & Laughter, 2016; Brown, 2017; Brown et al., 2019), there appears to be a gap between formal, culture-centered educational theories and practices in science centers. Dawson (2019) reflects upon this gap when recounting the research review of Falk et al. (2012/2015) which uncovered only 27 out of 553 peer-reviewed articles that investigated marginalized communities in ISE contexts. Current literature does not exhaust the ways that experiential-based educational theories fall short (Collins, 2000; Ladson-Billings, 1995) of addressing the institutional reform necessary to tackle DEI issues in ISE (Ash, 2022). Given the expressed focus on diversifying museums (Garibay & Olson, 2020) and the national push to make science centers more inclusive of communities of color (ASTC, 2022), it can be said that educational frameworks that address DEI issues like cultural relevancy are under-researched in ISE (Dawson, 2019).

To address the gap in research and to help ISE learning environments live up to their charge of bringing science to the broader public, more empirical research is needed on the educational theories that are useful for transforming institutional culture and the related practices that are successful at reaching diverse audiences. In order to achieve greater social inclusion, ISE institutions must build lasting relationships with diverse communities and solicit their cooperation throughout the design, planning, and implementation processes (Dawson, 2014b; Feinstein & Meshoulam, 2014; NRC, 2009). Science center educators (SCEs) as the intermediaries between science and the public, as well as between the public and science center leadership, are "ideally positioned to impact both administration and visitors" (Ash & Lombana, 2013, p. 70). Systemic changes to SCEs' perceptions and practices have been shown to positively influence acculturation within ISE environments (Ash & Lombana, 2013; DeGregoria, 2009; Seig & Bubp, 2008; Tran, 2008). At the same time, scaffolding the transformation of SCEs' perceptions and practices with critical educational pedagogy that centers culture has the potential to reculture science museums beyond the assimilation required for acculturation and towards true power sharing required for cultural equity (Ash & Lombana, 2013; Dawson, 2019).

A framework that articulates the characteristics of Culturally Relevant Education (CRE) in ISE settings would be valuable to ISE practitioners, researchers, and those who prepare and provide professional development to informal educators.

Purpose of this Study

The purpose of this study was to examine the perceptions and practices of SCEs regarding cultural relevancy in science centers, to make a case for applying critical educational frameworks to address DEI in ISE institutions, and to address the gap between formal educational research theories and practice in ISE learning environments. While SCEs act as brokers of science between the institutions where they work and the audiences they serve (Ash & Lombana, 2013) and their beliefs likely influence practices at ISE institutions (Ennes et al., 2020; Tran, 2008), the investigation of SCEs' beliefs and practices about CRE in science centers offers some insight into DEI issues in ISE contexts. This study explored how participating SCEs conceived of culture and cultural relevancy, what they believed about the role of cultural relevancy in ISE, and how they described practicing cultural relevancy in science centers.

Tackling DEI in ISE institutions requires culturally competent informal science educators. While Pedagogical Content Knowledge (PCK) describes effective K-12 teachers in formal classrooms (Park & Oliver, 2008; Shulman, 1986) and Culturally Relevant Pedagogy (CRP) describes the cultural competence of formal teachers (Ladson-Billings, 1995a), currently there is not a tested equivalent to PCK or CRP for informal science educators (King & Tran, 2017). If the PCK employed by effective informal science educators is unique (Geveke et al., 2017) and can be characterized as informal pedagogical content knowledge (ISE-PCK) (Busch et al., 2022), it is possible that the CRP of informal educators is also distinctive. A recent research study found that the awareness of the cultural context of the audience is a component of ISE-PCK (Busch et al., 2022). As the STEM pedagogy currently employed in the presentation of science in ISE institutions often fails to align with the principles of cultural inclusivity (Dancstep & Sindorf, 2018; Dawson, 2019), this study offers CRE, a critical educational theory, as a guiding framework to tackle cultural inequities in science centers. By adopting educational frameworks that center culture, ISE institutions can extend their pedagogical approach to reach more racially and ethnically diverse audiences (Ash, 2022).

Recognizing that it is not enough to attract only a select minority of society, science museum professionals want to make ISE learning environments more inclusive, welcoming places where diverse learners feel they belong (Ash & Lombana, 2013; Garibay & Olson, 2020). However, Feinstein and Meshoulam (2014) found that inclusive practices touted by ISE institutions, including efforts to recruit diverse staff and visitors, outreach programs to diverse communities, and modifications to the facility and exhibits, were frequently developed and undertaken without the inclusion of diverse perspectives. While some ISE institutions are making efforts to become more responsive to diverse audiences (Feinstein & Meshoulam, 2014), the prevalent cultural framework guiding ISE programs and exhibits design is euro-centric and therefore ill-suited to address issues of equity and access (Ash, 2022; Dawson, 2014a, 2019). Furthermore, the literature linking critical cultural theories of learning to ISE is limited (Ash & Lombana, 2013; Dawson, 2019). To address these issues and to model moving from formal education theory to informal education practice, this study adapted the CRE framework for use in ISE environments and applied it to characterize SCEs' perceptions and practices of cultural relevancy.

Culturally Relevant Education

Culturally Relevant Education (CRE), the theoretical framework for this study, informed the research approach--basic qualitative design, guided the investigational strategy—the study of science center educators' espoused beliefs, and was central to the development of the research tools—interview protocol and survey questions. The CRE framework, an outgrowth of CRP, recognizes that the social, historical, and cultural context of both the learner and the educator informs the learning process (Aronson & Laughter, 2016; Dover, 2013). CRE addresses the possible misalignment between the dominant culture of science and the culture of the learner by applying the lens of cultural relevancy (Aronson & Laughter, 2016; Brown et al., 2019).

By exploring CRE, SCEs participating in this study had the opportunity to confront their beliefs and practices vis-à-vis the relationship between their own culture, the culture of their institution, and the culture of their audience. Chapter 2 provides a detailed description of the theoretical framework that is the underpinnings of this study.

Research Questions

This study was guided by the following research questions and sub-questions:

1. How do science center educators (SCEs) conceptualize cultural relevancy in informal science education?
2. What are SCEs' perceptions of the role of cultural relevancy in science centers?
3. What are SCEs' current practices related to applying culturally relevant principles in science centers?
    a. What are SCEs' perceptions of ideal practices to improve culturally relevant education (CRE) in science centers?

b. What are SCEs' perceptions of supports for and barriers to applying culturally relevant principles in science centers?

Significance of the Study

The significance of this study is two-fold. First, this study offers potential practical contributions to the field of ISE—it applies the lens of cultural relevancy to the systemic inequities of ISE institutions by authentically centering culture and confronting the role of culture in science and science learning. Outcomes from this study show that CRE proves useful to categorize SCE's beliefs and practices regarding cultural relevancy in informal science settings and that this understanding can improve the attainment of DEI goals. Moreover, this study sheds light on guiding factors in science center educators' DEI efforts by exploring the relationship between their conceptions of CRE and their descriptions of educational strategies and practices used to scaffold their programs, science interpretations, exhibits, and audience interactions.

Secondly, in addition to learning how science center educators frame DEI practice, there is the potential to make intellectual contributions to the field of research by demonstrating how culture-centered educational frameworks similar to CRE can be adapted to informal science settings. This, theory-to-practice paradigm, models for science centers specifically, for the ISE field in general, and scholarship more broadly, a manner in which educational research can support ISE reform. With the adaptation of CRE for use in ISE, there is the opportunity to contribute to informal educator training on enacting DEI practices in informal settings. It is possible that a culturally centered framework modified for informal settings will help science center educators and those that train and evaluate them. Ultimately, this study might help bridge the gap between educational research and the educational practice of CRE in ISE institutions (Brown, et al., 2019).

Summary of Chapter One

While science centers utilize experiential-based concepts like constructivism, the educational pedagogy currently undergirding ISE institutions is ill-equipped to dismantle cultural and social inequities. An educational framework that critically centers culture while demonstrating inclusivity would benefit ISE institutions, practitioners, researchers, and professional development programs. Considering principles of cultural relevancy offers SCEs the opportunity to confront the possible conflict between their culture and the cultures of ISE audiences. In this study, I explored how SCEs conceptualized cultural relevancy, perceived the role of cultural relevancy in ISE, and described culturally relevant practices in science centers. By examining the perceptions and practices of SCEs, I support the development of a culturally relevant model that is applicable to informal science education settings.

Overview of Dissertation Structure

Organized in a single-paper structure, this dissertation is comprised of five chapters beginning with Chapter One, which provides the background and purpose of the study, comments on the problem the study seeks to address, provides research questions and theoretical framework, and offers an opinion on the significance of the study. Chapter Two reviews the current literature on the role of culture in science, discusses the beliefs of formal and informal science educators regarding culture and science, and further defines the CRE theoretical framework. In Chapter Three, the research design, study context, investigational and analytical procedures, participants, ethical considerations, and my personal positionality statement are described in detail. Chapter Four provides the study findings aggregated to respond to each research question and contextualized to present an analysis of the relationship between SCEs' perceptions and the four markers of CRE. Finally, Chapter Five synthesizes the major findings, discusses conclusions, and suggests several directions for future research.

CHAPTER 2

LITERATURE REVIEW

Science centers as cultural institutions are dynamically linked to the culture of the people that created, operate, and use them (Dawson, 2014a, 2019). Since the concept of culture is historical as well as contextual (Bang, 2015), it follows that builders and operators of science centers would fashion them from their own core values (Ash & Lombana, 2013) with consideration for the knowledge that they have gained from their experiences. As all people seek to create meaning from their experience of the world (Bang, 2015) and science is an endeavor created by people to explore the world, science, like science centers, reflects the culture of the people using it. Through colonialism, slavery, misogyny, and globalization White men have dominated the culture and politics of science (Dawson, 2019) and have erected practices of exclusion to inhibit the participation of other groups (Ash & Lombana, 2013). The culture and politics of science exist, even if they are "invisible" to people immersed in the dominant culture. Addressing the culture inherent in science education in both formal and informal settings is fundamental to understanding the barriers to science for people from minoritized communities. Understanding how the beliefs of science educators (again from both formal and informal institutions) affects their instructional practices is paramount to dismantling inequities in science engagement. Critical educational theories that center culture and have proven success in formal science education settings have the potential to address DEI issues in ISE environments.

Defining Culture

While researchers like Megan Bang (2015) rightfully warn us to remember that culture is dynamic and does not fit into a neat box identified by race and ethnicity, for the purposes of this study it is useful to offer some parameters in which to frame the concept of culture as it was a keystone to this research. Bang (2015) provided the following description:

> [Culture is] variably distributed and transformed within and across groups and involve[s] a reciprocal and evolving relationship between individuals' goals, perspectives, values, and their environment…[It] is both historically constituted and dynamically changing through participation in social practices and making sense of life. More simply put, all people explore, narrate, and build knowledge about their worlds, but they do so in varied ways that are dynamically linked to particular contexts. (p. 221)

This study examined culture on three levels—personal, institutional, and societal. On the personal level, SCEs participating in the study were encouraged to describe their own culture and critically reflect upon their cultural relationship with science. They also described the institutional culture at the science center where they worked. Additionally, participants defined the term *culture*.

The "Invisible" Politics and Culture of Science

Western science is embedded with political and cultural structures that go largely unnoticed by western scientists who fail to recognize the nuances of their own politics and culture as it affects their beliefs and practices (Martin et al., 2019; Rudolph, 2019). When the majority of scientists, technologists, engineers, and mathematicians in the US are White (Nadeem, 2021), and thus represent the dominant culture of the US, it may be challenging for the STEM world to acknowledge the cultural lens through which it operates (Carlone & Johnson, 2012; Gay, 2018; Howard, 2019). While some scientists in the US argue that science is neutral, factual, and objective (Reiss & Sprenger, 2020) because the lens through which they conduct science is the same as their own culture. It is similar to a person from the southeastern part of the

US meeting someone from Boston. The Bostonian can hear the southerners' drawl and immediately registers that the person has an accent. Meanwhile, the southerner hears the unique way people from Boston pronounce the letter "R" and think to themselves that this person is not from here. Neither person recognizes that they each have an accent. Similarly, some scientists claim that science is acultural and apolitical because, to them, the politics and culture of science are invisible (Carlone & Johnson, 2012). However, it is only invisible because it blends in with their own culture, which is the dominant culture of society. For individuals that are not members of the dominant population, and whose culture goes against the mainstream, the culture of science will be obvious (Carlone & Johnson, 2012).

While some argue that science is without culture and does not side with a political perspective, Aikenhead and Jegede (1999) assert that everything about science is cultural and political, from what scientists think about studying to the methodological choices they make and the tools at their disposal. What scientists know, believe, and think all play a role in what they decide to study and the manner in which they approach their investigations (Tlili, 2016). If science is defined as the discovery and understanding of the physical and natural world through systematic experimentation (Oxford Reference, 2021), then it is inescapably bound by the culture and politics of the people who develop those experiments.

Political Perspectives in Science

While science, in study and practice, is often presented as apolitical, it actually adopts the politics of the dominant population in society (Riley et al., 2014; Rudolph, 2019). During the time when the US was in a cold war with the Soviet Union, the race to space and the competition around Sputnik inspired science enthusiasm everywhere from the halls of academia to the living rooms of the general public (United States, 1983). Worried that the Soviet Union would outcompete the US with the launch of Sputnik, the US government commissioned top scientists to revise the educational system to ensure scientific and technological advancement (Rudolph, 2019). Scientists, instead of educationists, became responsible for school curricula, reflecting the country's respect for science (United States, 1983). US citizens considered themselves smart because they followed "the science." Science had won the hearts of the American people and the political favor of the US government.

Currently, however, there is a growing challenge to the veracity of science. For example, in many developed countries, there is currently a political struggle questioning the validity of scientific concepts and discoveries (Ball, 2018; Martin, 2017). During the Trump administration, and now in the post-Trump era, many members of the Republican Party, as well as Republican-supported news media, question the control science has on public life (Oreskes, 2021; Pazzanese, 2020). During the COVID-19 pandemic, public health scientists determined that the disease spreads through airborne transmission, and therefore recommended the use of facemasks and social distancing for public safety (Dallek, 2020; Slevin, 2021; Tollefson, 2020). In the first example, when faced with an agreed upon national enemy—the Soviet Union, the politics of science said that science is right and science equals truth. Yet, this time, when faced with a deadly disease, instead of wielding science as a unifying force, a national debate ensued in which people, split primarily along political party lines, agreed or refused to wear facemasks (Enriquez, 2021; McKelvey, 2020). The partisan politics of science is currently on display with one political party and its governing administration following scientific policy in opposition to the other. The support or vilification of science along political party lines is a contemporary reminder that science is not apolitical. These examples support the assertion that science is not apolitical, nor is it acultural.

Cultural Perspectives in Science

Science is not acultural, it adopts the culture of the dominant population in society (Howard, 2019). Since colonial times, European cultural practices have dominated the imagination, the policies, and the resources of the world (Aikenhead, 2006). The global dominance of European culture is also evident in the teaching and practice of science. Two examples of this dominance are the scientific naming convention and "the" Scientific Method.

Cultural dominance in science is exemplified by the scientific naming convention and the underlying concept that implies by naming something, one defines it and gives it meaning. The concept that a western scientist can "discover" something, although others have known it for centuries, speaks to the privilege of the dominant population (Cahan, 2020; Goldenberg, 2014). Although indigenous people have names for local plants and animals (Gillman & Wright, 2020), western science encourages its practitioners—scientists—to rename everything in a manner and language that suits them. Scientific naming conventions use European languages that western scientists are comfortable with (in most cases Latin) as opposed to the original name in the local indigenous language.

In defense of Eurocentric scientific nomenclature, some claim that it is important for scientists throughout the world to communicate without ambiguity for greater scientific collaboration and discovery (Gillman & Wright, 2020). They might argue that a common language is critical for scientific communication, which justifies the adoption of Latin species names. However, this rationale is faulty when one considers that the US is a multilingual, multicultural society and thus has adopted a multitude of words from various languages for use in American English. Words like Manhattan and chocolate are incorporated into American speech without further thought of their linguistic origins (Haugen, 2009). The fact that science does not use names and naming conventions based on the object's origin is just one example of its inextricable ties to the culture of the dominant population.

Cultural ties of science to Western culture are also reflected in the linear nature of "the" Scientific Method and its similarity to the Eurocentric concept of historical timelines. European-based societies tend to illustrate history and the passage of ages, using number lines (Pant, 2016). However, the historical traditions of indigenous people that are not from Europe incorporate the concepts of circular time, often using mandalas and calendar rounds to illustrate the passage of time (Fulmer et al., 2014). These indigenous cultures track the seasons that come again and emphasize the return of time in a manner that is more circular than linear. Similar to the teaching and learning of history, science in Eurocentric societies is taught as a linear process--beginning at one point and ending at another. Western science begins with a question or a problem, from which a hypothesis—an educated guess is derived (Voit, 2019). Based on knowledge that the researcher already possesses, the western scientist develops methods and gathers materials to try to solve the problem or to test the hypothesis (Baur, 2019; Voit, 2019). Then the scientist repeats these methods (also called experiments) several times to collect information (also known as data) on the problem. The next steps are to analyze the data and draw relative conclusions—or answer the question to determine whether the hypothesis was right or wrong. This set of procedures is "the" Scientific Method and it is the prescribed process of systematically investigating the physical and natural world (Baur, 2019; Emden, 2021; Voit, 2019).

However, that is not how science works in the real world. In actuality, science is more of a circular process, as opposed to a linear one (Baur, 2019; Emden, 2021). Science is not a flowchart that starts at one distinct point and flows down through predetermined steps. Rather, it is an iterative process that could begin at any step, that expands and contracts at different points, and that circles back to act upon the knowledge that is generated through findings (University of California Museum of Paleontology, 2012). One could begin the scientific journey by accessing the materials at their disposal and contemplating the questions that those materials could answer. Another point of entry might retest the methods and solutions asserted by other scientists. Scientists often go back to a previous step, for example starting with a question only to come up with another question, instead of a conclusion, once data is collected (Baur, 2019). Although in practice, science is a circular process, the teaching and representation of science as linear reflects Western cultural ties (Iaccarino, 2003).

Addressing Culture in Science Education

What we see in the discipline of science is also evident in science education (Aikenhead, 2001). Similar to science, science education is neither apolitical nor acultural, it favors some learners while at the same time disadvantaging other learners, and it perpetuates structural inequalities in deciding inclusion/exclusion power dynamics (Dawson, 2012, 2019). Additionally, science education is viewed through the cultural lens of middle-class, White educators who are often blinded to the structural inequities in the education system and the racial and cultural biases of Western science (Johnson & Bolshakova, 2015). For example, US science educational institutions in both formal and informal settings teach science as if it were truth, not theory, indoctrination instead of inquiry, and "the scientific method" as the only scientific process (Baur, 2019; Brown et al., 2019; Emden, 2021). Johnson and Bolshakova (2015) address the culture of science education by arguing the following:

> Mainstream science instructional materials up until recently have reinforced the traditional view of science as an area for predominantly Caucasian males…science continues to be taught as an overwhelmingly culture neutral subject—as teachers have

not learned how to integrate the variety of student backgrounds into the content to make it more accessible, engaging, and relevant. (p. 197)

The Role of Culture in Science Education in Formal Settings

Science education in formal settings includes twenty-two years of schooling for an individual who begins learning science in pre-kindergarten and continues taking science classes all the way through grade school, undergraduate and graduate university, until they receive a terminal degree. For the purpose of this research study, the discussion of science education in formal settings includes laboratory training through academic courses and science industry apprenticeships.

Science Culture in Schools. In the US, many schools promote a scientific culture that claims to be agnostic, acultural, and apolitical (Brown, 2006; Howard, 2019). They endorse the view that science does not choose sides because it is not political and it does not choose one culture over another because science does not have a culture. Yet, when students enter a science classroom, they enter the domain of the orderly classroom culture created by the teacher and the school (Howard, 2019). To address this issue, researchers like Michael Apple (2012) reflect on ways to protect disenfranchised students' agency in the face of alienation caused by elite cultural norms in subject areas such as science. Apple's research seeks to identify and disrupt the role of schooling that requires all students to assimilate into the culture of the population in power (Apple, 1986). On the other hand, most schools teach that science is objective and neutral. They promote the teaching of steps or procedures of science that are very unambiguous, ordered, and exact. In school, students often learn science by conducting labs that are like cookie-cutter recipes intended to give a predetermined result (Baur, 2019). If the student achieves the expected outcome, they got the answer correct, if they do not reach the desired endpoint, they got the answer wrong. These lessons send the message that there is a right way to do science and a wrong way and if someone does not follow the prescribed process, they are not actually conducting science (Emden, 2021; Lee & Buxton, 2008; Rudolph, 2019).

National science curricula like the Next Generation Science Standards (NGSS) and the National Science Education Standards (NSES) often claim the objectivity of science. For example, the NGSS says:

> Scientific inquiry is characterized by a common set of values that include: logical thinking, precision, open-mindedness, objectivity, skepticism, replicability of results, and honest and ethical reporting of findings. (NGSS, 2013)

The NGSS and NSES present "The Scientific Process" and "The Nature of Science," as very precise, fixed ideologies. At the same time, these curricular guides are specific to the culture of science which mimics the dominant culture of society and is adopted as the culture of the school (Howard, 2019; Rudolph, 2019).

The assumption that schools can teach any subject as acultural and apolitical, although the subject came from people with a culture, is only possible when the school's culture is the same as the dominant culture. In the US, it is a byproduct of White privilege to think of science as completely objective, apolitical, and acultural (Apple, 2012; Johnson & Bolshakova, 2015; Ladson-Billings, 1998). People of color, on the other hand, are unable to see science in that way. Students from a marginalized culture, or a marginalized population within a culture, are aware that who they are and what they do is different from the mainstream (Gay, 2018; Howard, 2019; Rudolph, 2019). Those that are a part of the mainstream may not notice the invisible culture and invisible politics of the school, because they are in the flow of the stream. However, those on the outside looking in are very much aware of the dominant culture of the school and of the science classroom. They are reminded every day that both the school they attend and the science they are trying to learn have the same culture and it is not their culture (Dawson, 2014b; Howard, 2019).

Science Culture and Politics in Laboratories. In science laboratories across the US, apprentices and interns learn laboratory culture through instruction, on-the-job training, and mentoring. Through modeling, trainees learn how to behave in a laboratory setting, what to wear, how to speak, and even what to listen to on the radio (Thoman et al., 2017). Scientists within these labs might explain to trainees that following their standard operating procedures is the best or only way to conduct science, that it will help prevent mistakes, or simply state that this is the way science has always been conducted. All of these written and unwritten rules come from the dominant culture (Brown et al., 2016).

In addition to spoken and unspoken rules, lab investigators, technicians, and directors promote laboratory culture through mentoring interns and apprentices and by demonstrating acceptable laboratory practices and behaviors (Davis & Jacobsen, 2014; DeAngelo et al., 2016). This is also how individuals that are not from the dominant population become acculturated to the culture of science (Antes et al., 2018). In this manner, students from underrepresented groups replicate their science mentors, and the culture and politics of western science is entrenched in laboratories and propagated throughout the world (Joseph, 2012; Smith & Hopkins, 2004). For example, Brown et al. (2016) reflected on the rules of laboratory culture in their exploration of the sense of belonging in African American science students compared to African American scientists. They reported on the alienation from communities of practice, subtle racism, and other forms of microaggressions that obstructed the STEM pipeline from student to science professional for African Americans (Brown et al., 2016).

Once again, for apprentices and interns that are members of the dominant population, the cultural and political background of the lab's systems might not be easily recognizable (Ong et al., 2018). However, individuals coming from cultures outside of the mainstream, often have to code-switch to make the transition from their home culture to the laboratory culture (Joseph, 2012; Ong et al., 2018). For example, on a ride that takes two city buses from the urban, predominantly African American and Hispanic neighborhood, to the exclusive, affluent European American community where the marine laboratory is located, an intern of color will likely change more than just her bus. She might change her clothing, her speech cadence, and possibly the way she wears her hair. She will have to make the same changes in the reverse to journey back to her home community. Apprentices of color quickly learn that it is not acceptable to behave or look the same in both places because the culture of the laboratory and the community are not the same (Brown et al., 2019; Pietri et al., 2019). This example describes codeswitching, which many students of color find essential to fit in and be successful in both environments (Charleston et al., 2014; Wilkins-Yel et al., 2019).

In another example, the intern of color that rides two buses to reach the laboratory will come early to work because that is when the bus arrives for the only bus route available. He will forego the long lunch with the European American interns and lab staff because he has to complete his tasks before the last bus, which leaves at dusk, heads back to his community. He will miss the conversations at lunch and the lab meetings that happened in the evening. The perception would be that he did not work as hard as the other interns did, although he clocked the same number of hours. The affluent residents of the community where the laboratory is located do not want urban people of color in their community after dark and thus the bus stops running at dusk (Ong & Miller, 2005; Spieler, 2020). This is yet another reminder that science apprenticeships are political and controlled by Western science culture.

The Role of Culture in Science Education in Informal Settings

Informal science education can take place in a variety of settings from afterschool programs and summer camps to science centers. For the purpose of this research, the term "science center" refers to institutions that have informal science education as part of their mission, including but not limited to science museums, zoos, botanical gardens, aquariums, planetariums, interpretive science and technology centers, and children museums with a science focus (Rennie, 2014). Science education in informal and out-of-school settings has adopted the same politics and culture of science in formal settings like schools and laboratories (Adams et al., 2012; Rennie, 2014).

Science Culture in Afterschool Programs and Summer Camps. Science in afterschool programs tends to mirror the politics and culture of science in formal settings (Lundh et al., 2013). The audiences for afterschool programs are generally the same as those in the science classroom—students that attend the school. Afterschool programs are often located on school campuses to take advantage of the classroom space that is available after traditional school hours (Falkenberg et al., 2006). The location dictates the culture since the physical structure is oftentimes a traditional classroom with desks and chairs oriented towards the teacher or board at the front of the room. While this may be convenient for families and program administrators, unfortunately, it means that the culture and politics of the school permeate the afterschool program (Howard, 2019; Lundh et al., 2013). Another example of afterschool science programs reflecting the culture and politics of formal settings is the experiments that students conduct in afterschool programs, which are very similar to hands-on activities from science classes (Huang

& Dietel, 2011; Lundh et al., 2013). While there may be more field trips, excursions, and hands-on activities during the afterschool program, the premise is the same as in formal science education—that there is a scientific process and certain rules students must follow. This process and the rules associated with it come from the dominant culture (Howard, 2019; Rudolph, 2019).

Summer science camps often adopt the same language and curricula as formal science education as they attempt to meet national science standards (Antink-Meyer et al., 2016; Seung et al., 2019). In this way, the culture in science summer camps mirrors the culture of formal science in school and lab settings (Smith-Palmer et al., 2015). While summer camps tend to be more activity-based like afterschool programs, the experiments are very similar to school experiments in that they provide recipe-like lists of materials and procedures and participants receive the reward of the right answer if they follow the steps exactly or a wrong answer if they do not. Since the camp activities often stem from science curricula, they operate within the same rules of science defined by the dominant culture (Smith-Palmer, et al., 2015).

Science Culture in Science Centers. Similar to afterschool programs and science summer camps, most science centers operate through the lens of the culture and politics of the dominant population (Dancstep & Sindorf, 2018). Science exhibits in science centers often display and interpret scientific concepts from a Western cultural and political perspective (Dawson, 2014a; Duensing, 2006). The culture and politics of the dominant population are unescapable and are almost like propaganda, as science centers seek to impress upon their audiences the importance of science (Bandelli & Konijn, 2013). When audiences enter a science center, everything from the visual images on the walls, the color palette of the paint, carpet, and furniture, to the background music or piped-in "white noise," screams to them that this is a place for European American culture (Bandelli et al., 2009; Dawson, 2014a). The language and speech cadence of the staff as well as their racial background and placement in the facility reflect the dominant culture (Dawson, 2014a; Garibay & Olson, 2020). In this way, science centers have adopted the same politics and culture as science education in formal settings.

Science centers not only derive their theoretical perspectives from the dominant culture they also perpetuate this dominance by framing "which parts of science are important, and, which parts ought to be publicly available or discussed," and by maintaining forms of social exclusion (Dawson, 2012, p. 32). In her book *Equity, Exclusion and Everyday Science Learning*, Dawson (2019) discussed having a first-row seat to view the exclusionary practices of ISE institutions. It was during her time as an SCE that she became aware of the lack of diversity and inequitable practices of ISE. Dawson said:

> As a former museum employee, I knew it was as easy as looking across a crowded gallery to know science museums were not very inclusive. Surprisingly, at that time (the mid-2000s), little research was available about how exclusion from everyday science learning worked, let alone how such practices could become more inclusive. My colleagues and I found that job titles like 'Community Officer' and 'Diversity Manager' were sometimes used by our institutions to partition equity issues off from day-to-day work, often (though not always) against the best intentions of those involved. (p. 109)

Dawson further explains that the solution to the exclusionary practices of science centers is not the forced assimilation of people of color to the White middle-class cultural norms reflected in most ISE institutions (Dawson, 2014b). The changes required for non-traditional visitors to assimilate are counterproductive to the goal of diversifying science center audiences because they attempt to produce cookie-cutter copies in order to maintain the status quo. Rather, as Ash (2022) puts it, ISE institutions must relinquish the "noncollaborative outreach stance, explicitly or implicitly focused on changing museum outsiders so that they can learn to assimilate and learn to imitate the 'museum norm' (p. 23).

Falk and Storksdieck (2005) underscored the importance of informal science education (ISE) institutions considering the sociocultural context of non-traditional museum visitors. Sociocultural Learning Theories are central to research on the relationship between learning and culture. They center social context in a way that allows researchers to explore the role of culture in learning (Nasir & Hand, 2006). Evidence for this social context can be found in the conversations and interactions of families as they visit ISE institutions (Weiland, 2015). Currently, this interaction is largely guided and in the case of diverse visitors, also restricted, by the culture of the institution, which mirrors European American culture. In other words, while science centers may adopt the concept that audiences construct their own knowledge, without considering their unique cultural backgrounds, these institutions will fail to reach diverse visitors (Dawson, 2014a). The very vibe—the atmosphere of the environment——informs audiences that the science center aligns with and promotes the culture of science, where they claim to be apolitical, acultural, and objective while being steeped in Eurocentric culture.

Science Educators' Beliefs and Cultural Relevancy in Science Education

Educators, like everyone else, rely upon their belief systems to help them make sense of their experiences and to give meaning to the world (Jones & Leagon, 2014; Villegas, 2007). Beliefs inform the instructional goals and practices of educators in both informal and formal contexts and influence their thoughts and actions inside and outside of educational spaces (Rudolph, 2019). Educators' beliefs about the concept of culture, the culture of science, and their own culture affect their pedagogical views and instructional practices (Howard, 2019).

Formal Science Educators' Beliefs about Teaching and Learning Science

Throughout this study, the labels teachers, instructors, and professors are used interchangeably to refer to educators that work in formal contexts like K-12 schools, colleges, and universities. When studying the complex relationship between what science teachers believe and their practices in science classrooms, it is helpful to distinguish between espoused and inferred beliefs. Bryan (2012) describes espoused beliefs as "self-reported claims" collected by asking teachers questions via surveys, questionnaires, and interviews. On the other hand, she describes field observations as the technique most commonly used to infer teachers' beliefs based on their actions (Bryan, 2012).

Science teachers' beliefs about teaching, learning, and knowing science are shaped by their culture and their experiences (Castro, 2014). What a teacher believes is based on what they have seen, what they know, and the environment in which they grew up. Their beliefs are therefore shaped by their own culture and politics, as well as how they use that culture to interact with the world (Mansour, 2009). When teachers do not believe in a certain concept or understanding it is very hard for them to incorporate it into their teaching style or into their pedagogical beliefs (Bryan & Atwater, 2002; Byrd et al., 2011). For example, Johnson and Bolshakova (2015) when describing the use of Culturally Relevant Pedagogy (CRP) reported "the process of enabling existing teachers to adopt all aspects of CRP has been met with some difficulty" because it is contrary to their perspective of the role of education (p. 180). Johnson and Bolshakova (2015) noted:

> Teacher beliefs are often difficult to address and change. This is especially true when speaking of changing their beliefs about the role of culture within the classroom, outside of the classroom, including their own cultures, as well as their students. (p. 179)

Teachers' beliefs inform their instructional practices (Castro, 2014; Villegas, 2007). What a teacher believes is the foundation of how they teach and even what they teach.

Science Teacher Beliefs about Science Culture. Many science teachers have apolitical and acultural beliefs about science (Barton & Yang, 2000). They may believe that science is objective and is therefore apolitical and acultural. On the other hand, some science teachers acknowledge the subjectivity of science, recognize that science operates within the boundaries of the dominant culture, and think critically of science culture (Bryan, 2012; Reiss & Sprenger, 2020). These science teachers are critical of their own culture while remaining aware of and open to others' cultures (Johnson & Bolshakova, 2015). When science teachers appreciate and celebrate the culture of other people, they have more success with students of color inside their science classrooms (Aronson & Laughter, 2016; Brown et al., 2019).

Science teachers' beliefs about the political and cultural nature of science inform their teaching and class culture. Science teachers that believe science is acultural and apolitical will teach science from a perspective that promotes science as objective, true, and exact. On the other hand, science teachers that have a critical view of the culture and politics of science, as well as a critical view of their own culture will understand that science has adopted the culture of the dominant population (Bryan, 2012; Ladson-Billings, 1998). With this understanding, the critical science teacher will be able to incorporate other populations' cultural and political views into their teaching of science. The critical science teacher recognizes that the cultural and political ties to science have to be deconstructed to be able to teach in a more inclusive way (Ash, 2022; Dawson, 2019).

Informal Science Educators' Beliefs about Teaching and Learning Science

For the purpose of this study, informal educators that work to develop or deliver programs and exhibits at science centers (zoos, planetariums, aquariums, science museums, science and technology centers, nature centers, botanical gardens, etc.) are referred to as science center educators. In that vein, science center educators are defined as anyone who works to develop or deliver programs and exhibits to audiences (school groups or the general public within these institutions). This includes staff and volunteers that develop programs, deliver programs, develop exhibits, and interpret exhibits.

Similar to teachers in formal settings, science center educators' beliefs are shaped by their culture and experiences. Their beliefs are based on what they've experienced, what they know, and their culture. Studies show that the vast majority of science center educators in the US are European Americans, oftentimes females between the ages of 20 and 30, and from middle to high social economic status (Ruffo, 2013). This is very similar to the demographics of science teachers in public and private schools across the US (NSB, 2021). Science educators' beliefs are shaped by their culture and their experiences (Bryan, 2012; Bryan & Atwater, 2002; Jones & Leagon, 2014) as a relatively middle-class to wealthy and highly educated white female growing up in the US. Science center educators' beliefs influence their educational practices (Ennes et al., 2020). Similar to formal science teachers, how they interpret science, how they interpret exhibits on the floor, and how they present programs are based on their beliefs, which are based on their culture and their experiences (AAM, 2022; Ash, 2022; Dawson, 2019).

Science Center Educator Beliefs about Science Culture. Some science center educators may believe that science is factual and therefore apolitical and acultural (Dawson, 2014a). Their insider status inhibits them from seeing that science rests firmly within their dominant culture and the pervasive European American politics (Dawson, 2019). Other science center educators are in touch with their own culture, have culturally critical views of science, and experience success while working with audiences of color (Ash, 2022; Dawson, 2019). Similar to formal science teachers, science center educators' beliefs about the political and cultural nature of science are likely to inform their practices at science centers including instruction, interpretation, and program and exhibit development (Ennes et al., 2020). Unfortunately, there is a gap within the existing literature on the relationship between the beliefs and instructional practices of science center educators (Dawson, 2014b; Ennes et al., 2020; Johnson & Bolshakova, 2015). Additional research studies that explore the perceptions of science educators regarding the role of cultural relevance (Aronson & Laugher, 2016) in ISE learning environments like afterschool programs (Brown et al., 2019) and science centers (Dancstep & Sindorf, 2018) are warranted.

Theoretical Framework

While the scholarly community agrees that strongly held beliefs are resistant to change, it does not rule out the possibility of transformations in the beliefs and actions of science educators (Bryan, 2012; Jones & Leagon, 2014). Jones and Leagon (2014) help to make the argument for why science educators' beliefs and perceptions matter in relation to the implementation of ISE in increasingly diverse populations. They recognized the intersection between worldview, culture, and beliefs about science when they claimed, "science teachers' belief systems are clearly embedded in specific contexts, experiences, and cultural frameworks," (Jones & Leagon, 2014, p. 839). Any movement to reform ISE will necessarily include the revision of informal science educator beliefs and practices and must occur within the context of understanding their cultural frameworks.

As an example of the need to expand educational theories used in ISE, Jean Piaget's (1970) constructivism, often cited in ISE practice, can account for concrete experiences and the use of dialogue, however, it does not go deep enough to tap into the ethics of caring and personal accountability. The ethic of caring, "suggests that personal expressiveness, emotions, and empathy are central to the knowledge-validation process," (Collins, 1989, p. 766). Like Vygotsky (1978), Collins places the role of culture central to the development of consciousness (Collins, 1989). In sharp contrast though, Collins' ethic of personal accountability requires that "not only must individuals develop their knowledge claims through dialogue and present those knowledge claims in a style proving their concern for their ideas, people are expected to be accountable for their knowledge claims" (Collins, 2000, p. 265).

This expectation for knowledge accountability has brought greater focus on the role of the educator and the links between beliefs and instructional practices (Lumpe et al., 2012). The relationship between teachers' beliefs and their actions in the classroom is a topic of investigation by generations of educational researchers (Clark & Peterson, 1986; Lumpe et al., 2012). Although decades of research have not produced one distinct definition for the construct of beliefs, Lynn Bryan argues that there is "a consensus that beliefs are part of a group of psychological constructs that describe the structure and content of human thought that is presumed to drive a person's actions," (Bryan, 2012, p. 478). Furthermore, several studies found direct links between science teachers' instruction and their beliefs, noting that it draws influence from their perceptions of themselves and their students (Brickhouse, 1990; Laplante, 1997; Bryan, 2012). Granted, these researchers cited finding from studies investigating science educators in formal classroom settings, ISE researchers also found that educators in ISE environments are similarly influenced by their beliefs (Ash & Lombana; Ennes et al., 2020).

Jean Piaget (1970), Lev Vygotsky (1978), and John Dewey (1897) are three theorists considered by some to be the fathers of modern-day educational philosophy. Each proposed his own variety of constructivism: Piaget developed Cognitive Constructivism, Vygotsky countered with Social Constructivism, and Dewey, less concerned with being a purist, was a proponent of Transactional Constructivism. ISE institutions weave these three theories together to produce the theoretical fabric from which they cut their programs and exhibits (Ash, 2022). Historically, the dominant learning theories of ISE institutions evolved from behaviorists to constructivists and most recently to sociocultural epistemologies (Rennie, 2014). The twenty-first-century museum floor is packed full of hands-on/minds-on science exhibits that take the visitor on a journey from where they are, to the deep crevices of science knowledge. The idea is for visitors to navigate their way through interactive programs and exhibits and, with the aid of capable museum staff, construct new scientific understanding.

However, it is difficult to measure the learning outcomes associated with science museums, because their impact is variable and depends upon "the personal, social and physical contexts of the visit" (Rennie, 2014, p. 122). Current research on science museums focuses on exhibits, visitor learning experiences, technology usage, school field trips, family visits, and teacher support and professional development. Trends in visitor studies reveal the deconstruction and reconstruction of science knowledge by the museum visitor (Rennie, 2014). This method of learning is similar to Piaget's concept of a disequilibrium that ushers the learner from assimilation to accommodation. The museum staff and exhibit developers recognize the difficulty in appealing to visitors that might feel frustrated when trying to understand complex scientific ideas. Reflecting their somewhat pragmatic nature, science museums have been criticized in the literature for presenting science as "facts" as they fulfil their Vygotskyan role to mediate and re-interpret "official science" (Rennie, 2014).

In a very Deweyan fashion, science museums present science topics that seem most relevant to societal experiences. This aligns with William James' notion (originally published in 1907) "that ideas (which themselves are but parts of our experience) become true just in so far as they help us to get into satisfactory relation with other parts of our experience" (James, 2008, p. 44). Yet, it brings up the question of relevance to whom, who is the "us" that is being referenced? If the science museums are not relevant to all walks of society, they risk further alienating science processes from their very human context. In effect, they perch science processes on top of ivory white towers, out of reach of everyday people from non-dominant cultures. The dearth of science museum research concerning women, economically disadvantaged persons, ethnic minorities, and even adult learners (Rennie, 2014), is indicative of this practice. The scarcity of diversity in museum staff, visitors, and programmatic themes pose problems for museums in their role of science interpreters for the public.

While Vygotsky and Dewey focused on the role of culture in learning, their theories are not one-size-fits-all explanations for the cognitive development of children from subordinate cultures. Dewey's very first proclamation at the beginning of his article, My Pedagogic Creed, states that he believes "All education proceeds by the participation of the individual in the social consciousness of the race…through the stimulation of the child's powers by the demands of the social situations in which he finds himself" (Dewey, 1897, p. 77). This definition of education further subjugates the oppressed to perpetually live out their lives under the restriction of their oppressor. Dewey is not alone in this omission of the role of subjugation in learning. None of the foundational theorists reviewed thus far comment upon the material conditions and historical circumstances of the conquered child. Perhaps, their zone of proximal development is too vast and they cannot fathom that which they have never experienced. Arguably, these theories are inadequate to address issues of equity and access (Dawson, 2014b, 2019), and a more targeted theoretical framework is required.

As the existing approach to presenting and learning science in ISE institutions is a blend of Piaget's, Vygotsky's, and Dewey's separate versions of constructivism, visitors will encounter exhibits with relatively low (or sometimes no) instructional signage. They are expected to construct their own knowledge through experimentation and work through their frustrations unassisted. On that same museum floor, there might be a public program in progress where trained museum staff will act as more capable others and guide visitors through a difficult science concept. Science centers have gone to great lengths to assimilate the prevalent learning theories of the dominant culture. Belief systems that espouse the fallacy of the apolitical/acultural nature of science rely upon the unconscious loyalty to this belief by those placed in charge of educating the public.

CRE is an inclusive framework that describes educational opportunities designed to consider and preserve the culture and experiences of the learner while maintaining high levels of academic excellence and advanced skill transfer (Aronson & Laughter, 2016; Dover, 2013; Kotluk & Kocakaya, 2018; Ladson-Billings, 1995b). CRE is positioned to address issues of DEI through the enactment of four markers that support the relevancy of culture: the connection of culture to academic skills and concepts, the competence and critical reflection of culture, and the use of culture to critique discourses of power (Aronson & Laughter, 2016). While the use of CRE to enact DEI is well-researched in formal educational settings (Brown-Jeffy & Cooper, 2011), there is a small amount of literature supporting the use of CRE in formal science education contexts (Aronson & Laughter, 2016). The systematic literature review, "Comparing Culturally Relevant Practices in Formal and Informal Science Settings," (Kudumu, 2021) suggests that more research is needed that focuses on the perceptions and practices of CRE by educators at informal science centers.

Culturally critical theories have been utilized for formal science education and in a few research studies, also in informal science education. For this research study, I adapted the Culturally Relevant Education (CRE) framework described by Aronson and Laughter (2016) to explore the beliefs and practices of informal educators regarding cultural relevancy in science centers. CRE, as the theoretical framework that guided this study, informed every aspect of the research design, methods, and procedures. The four markers of CRE, described in more detail later in this chapter, provided background for the interview questions and served as a priori codes for the codebook during the deduction portion of data analysis. Finally, CRE supported my synthesis of findings by providing a framework to organize the perceptions of SCEs as they applied cultural relevancy to tackle issues of DEI at their science centers.

Culturally Relevant and Responsive Pedagogies

Culturally relevant and responsive pedagogies challenge social, cultural, and political structures that disenfranchised non-dominant populations by placing them and their cultures at the center of instruction. These ways of teaching intentionally bring non-dominant cultures from the fringes to the center of science instruction not just by incorporating examples, but also by incorporating the actual structures of these cultures into the practices of science.

Critical Pedagogy and Cultural Difference Theory. Critical Pedagogy and Cultural Difference Theory are the foundations of Cultural Pedagogy. Critical Pedagogy comes from Critical Race Theory when Ladson-Billings and Tate (1995) adapted Critical Race Theory and other critical theories, which were used primarily in the law profession, for educational research. These pedagogies are known as critical because they deconstruct educational theories and practices and require educators to be cognitively aware of the role race, gender, and socioeconomic status (SES) play in educational practice (Howard, 2019). Cultural Difference Theory is the understanding that schools have a culture, it is the culture of the dominant population, and it is not the culture of marginalized populations (Howard, 2019; Ladson-Billings & Tate, 1995; Rudolph, 2019). Cultural Difference Theory (CDT) addresses issues of academic success in non-dominant populations, specifically students of color. CDT asserts that the student does not need to be changed to match the school culture, rather, changes need to be made to the school to make it a more inclusive culture for learning as opposed to solely mirroring the dominant culture of society (Ash, 2022; Howard, 2019).

Critical Pedagogy was developed when researchers applied models from Critical Theory to explore the relationship between teaching and learning to the broad concepts of culture, social justice, democracy, and race (Freire, 1970/2018; Giroux, 2020). Ladson-Billings and Tate (1995) applied critical race theory (primarily used in legal scholarship) to the field of education to create "radically new paradigms that ensure justice" and as "a radical critique of both the status quo and the purported reforms," (Ladson-Billings & Tate, 1995, p. 62). Similarly, Cultural Difference Theory accepts the notion that school culture exists, is a reflection of dominant culture, and is different from the culture of marginalized students, while challenging the idea that the solution for underachievement is to change the learner (Carlone & Johnson, 2012; Howard, 2019).

Culturally Relevant Pedagogy. Culturally Relevant Pedagogy (CRP) asserts that effective teachers of African American students ensure that their students experience academic success, develop and maintain cultural competence, and develop critical consciousness. Gloria

Ladson-Billings built upon critical pedagogy and cultural difference theory when she developed CRP, a theoretical model that encourages individuals to keep their cultural identity while still achieving academic success (Ladson-Billings, 1995). It was originally developed to address the educational needs of African American students and has since been applied to Native American and Hispanic American populations, as well as marginalized communities throughout the world. Ladson-Billings stresses that her tenets of CRP are the pedagogical theory behind what is just good teaching. Julie Brown in her 2017 meta-synthesis of culturally responsive and inquiry-based science education, points to cultural difference theory (an educational theory researched in the 1950s) and critical pedagogies (especially critical race theory) as the theoretical underpinnings of CRP (Brown, 2017).

CRP asserts three criteria or propositions: (a) students must experience academic success; (b) students must develop and/or maintain cultural competence; and (c) students must develop a critical consciousness through which they challenge the status quo of the current social order (Ladson-Billings, 1995b). CRP challenges teachers to produce academically successful, culturally competent, and socio-politically conscious students (Ladson-Billings, 1995).

Culturally Responsive Teaching. Based on her understanding of critical pedagogy and cultural difference theory, Geneva Gay developed Culturally Responsive Teaching (CRT) as a framework for in-service and pre-service teachers to develop knowledge, skills, attitudes, and practices to improve educational outcomes of students of color. While Ladson-Billings and Gay both focused on students of color, they approached their research from different perspectives. Ladson-Billings' researched proposed outcomes—what students should have at the end of the educational experience. On the other hand, Gay researched the development of the teacher—what teachers need to do and be to ensure that the students have academic success.

Geneva Gay, in her 2002 article entitled, “Preparing for Culturally Responsive Teaching,” moved beyond theory into practice to provide a framework for in-service and pre-service teachers to develop the knowledge, skills, and attitudes needed to improve the educational outcomes of students of color (Brown, 2017; Gay, 2002). According to Gay:

> *Culturally Responsive Teaching* is defined as using the cultural characteristics, experiences, and perspectives of ethnically diverse students as conduits for teaching them more effectively. It is based on the assumption that when academic knowledge and skills are situated within the lived experiences and frames of reference of students, they are more personally meaningful, have higher interest appeal, and are learned more easily and thoroughly. (p. 106)

Brown (2017) described culturally relevant and responsive pedagogies as challenging social and political structures that disenfranchise learners. By extension, she noted:

> It follows that equitable learning experiences require students’ cultural and linguistic backgrounds be engaged as resources for science instruction, thereby easing border crossing between the dominant cultural practices of mainstream schooling and those practiced at home. (p. 1146)

Both CRP and CRT affirm the learner’s historical background, personal experiences, and individual and communal identities (Brown, 2017). These pedagogies have been employed in numerous educational research studies to analyze changes in the beliefs and practices of study participants.

CRP and CRT have become mainstays in educational research and pedagogy (Laughter & Adams, 2012). Weiland (2015), for example, uses the Culturally Sustaining Pedagogy framework, which is based upon CRP and CRT, to understand critical opportunities for Hispanic populations to learn in science centers. CRT challenges the deficit perspective of differences as learning barriers and highlights individuals' strengths within the context of their sociocultural uniqueness. CRP is based upon the premise that learning opportunities situated within culturally relevant and cognitively meaningful contexts will have greater success at engaging diverse learners.

Culturally Relevant Education

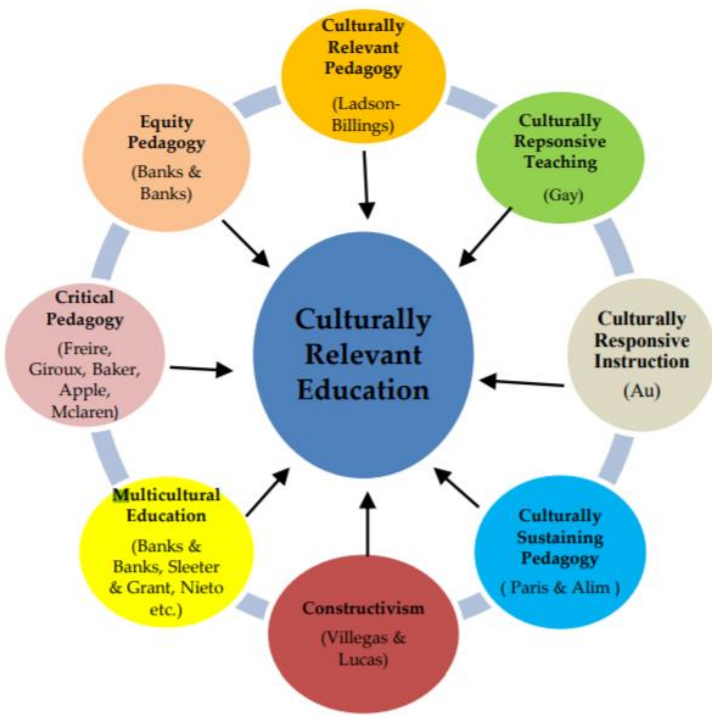
Culturally Relevant Education (CRE) came out of the different culturally responsive and relevant pedagogies. CRT and CRP spawned a number of different culturally relevant and culturally responsive teaching theories and techniques. Dover (2013) coined the term and defined the concept of culturally relevant education. Educational opportunities designed with the whole person in mind that consider and preserve the culture and experiences of the learner, while maintaining high levels of academic excellence and advanced skill transfer is the definition of culturally relevant education (Aronson & Laughter, 2016; Brown, 2017; Brown et al., 2019). Aronson and Laughter (2016) described its enactment in formal school settings for various subject matters including science and math. They described the organizing principles of culturally relevant education to be academic skills and concepts, critique of discourses of power, critical reflection, and cultural competence. Each of these is described in detail with examples given in the subsections below.

Since Ladson-Billings' and Gay's seminal articles defining CRP and CRT, there have been numerous adaptations designed to address the need for cultural considerations in teaching and learning. According to Kotluk and Kocakaya (2018), the pedagogical theories that predated CRP (constructivism, multicultural education, critical pedagogy, and equity pedagogy), as well as the theoretical frameworks that were born in the wake of CRP (Culturally Responsive

Teaching, Culturally Responsive Instruction, and Culturally Sustaining Pedagogy), contribute to the ideals that are the foundation of CRE. Kotluk and Kocakaya (2018) provide a visual representation of the fundamentals of CRE through the theoretical pedagogies that contributed to its development (see Figure 2).

Figure 2

The Fundamentals of Culturally Relevant Education



Note. This model cites the eight educational pedagogies that are the foundation of CRE. From "Culturally Relevant/Responsive Education: What do teachers think in Turkey?" by N. Kotluk and S. Kocakaya, 2018, *Journal of Ethnic and Cultural Studies*, 5(2), p. 100. Copyright 2018 by Journal of Ethnic and Cultural Studies.

As CRP morphed from a pedagogy primarily concerned with addressing the need for teachers to engage African American students, to a framework embraced by researchers studying other minoritized communities, modifications were made to include additional factors like language (Paris, 2012). Augare et al. (2017) discussed how language is used in the Native Science Field Centers that engage the communities they serve "in environmental science activities through the integration of traditional Native ways of knowing (understanding about the natural world based on centuries of observation including philosophy, worldview, cosmology, and belief systems of Indigenous peoples)" (p.227).

The concept of science being either cultureless or the sole providence of European-based cultures is being refuted by researchers of CRE in informal science. According to McRae (2018), when educators acknowledge the "cultural perceptions of science concepts," indigenous students are more engaged in science. Leonard et al. (2016) suggested:

> Equitable teaching in STEM, whether it is in mathematics or science, rejects deficit theory and embraces culturally responsive pedagogy, which values the cultural and social capital students bring to the learning context with the ultimate goal of improving preparation, broadening participation, and increasing the contributions of underrepresented minorities in STEM. (p. 356)

The Organizing Markers of CRE

In their review of CRE research, Aronson and Laughter (2016) graphically represented the relationship between the tenets of the CRP and CRE frameworks, constructed statements to characterize the "markers of CRE," and utilized their product to synthesize research across formal education content areas. Table 1 summarizes and compares Aronson and Laughter's (2016) CRE statements, Dover's (2013) four CRE markers, and Ladson-Billings' three tenets of CRP. The markers described below are the armature, the structure, on which CRE is built. The markers establish a basis to evaluate educational practices on the principles of academic skills and concepts (AS&C), cultural competence (CC), critique discourses of power (CDP), and critical reflection (CR).

Table 1

CRE Markers: Synthesizing Aronson and Laughter, Dover and Ladson-Billings

CRE Markers (Dover, 2013)	**CRE Statements** (Aronson and Laughter, 2016; p. 167)	**CRP Tenets** (Ladson-Billings, 1995a, 1995b)
Academic skills and concepts (AS&C)	"Culturally relevant educators use constructivist methods to develop bridges connecting students' cultural references to *academic skills and concepts*. Culturally relevant educators build on the knowledges and cultural assets students bring with them into the classroom; the culturally relevant classroom is inclusive of all students."	Academic achievement
Critical reflection (CR)	"Culturally relevant educators engage students in critical reflection about their own lives and societies. In the classroom, culturally relevant educators use inclusive curricula and activities to support analysis of all the cultures represented."	Cultural competence
Cultural competence (CC)	"Culturally relevant educators facilitate students' cultural competence. The culturally relevant classroom is a place where students both learn about their own and others' cultures and also develop pride in their own and others' cultures."	Cultural competence
Critique discourse of power (CDP)	"Culturally relevant educators explicitly unmask and unmake oppressive systems through the critique of discourses of power. Culturally relevant educators work not only in the classroom but also in the active pursuit of social justice for all members of society."	Sociopolitical consciousness

Academic Skills & Concepts. Aronson and Laughter (2016) described Academic Skills and Concepts (AS&C) as:

> Culturally relevant educators use constructivist methods to develop bridges connecting students' cultural references to *academic skills and concepts*. Culturally relevant educators build on the knowledges and cultural assets students bring with them into the classroom; the culturally relevant classroom is inclusive of all students. (p. 167)

For some researchers building on the knowledge and cultural assets of participants is how they conceptualized CRE (Aghasaleh et al., 2018; Dupuis & Abrams, 2017; Griep et al., 2016; Harper, 2016). Harper (2016) discussed building science identities in refugee students:

> For students from first generation refugee families who have experienced the trauma of violence and long-term displacement, the identification and retention of indigenous knowledge systems is critical to re-building their cultural identity as well as building their identity as science learners. (p. 1033)

Harper (2016) and other authors achieve excellent AS&C in their programs by using constructivist methods to engage participants, demonstrate respect for world cultures, and support the preservation of indigenous science knowledge. Dupuis and Abrams (2017) demonstrated how in Montana these methods have paid off:

> Montana has been a cultural leader in the United States, having included not only a statewide culturally relevant curriculum, but also a standardized test, which includes test items based on American Indian knowledge. (p. 602)

At the same time, Harper warns that Montana's success has been "on a very small scale" because of the small number of related items added to the test. Harper (2016) stresses the need for "culturally relevant training for teachers, increased funding support for low SES schools, and a greater focus on the construction of test items and curriculum so as to attend to the cultural construct" (p. 602). Griep et al. (2016) also reports on efforts to scaffold science concepts with "culturally relevant laboratory experiences from chemistry to other science courses at participating colleges" that serve Native American populations (p. 142).

In terms of AS&C, CRE has been conceptualized as building bridges through identifying, validating, and retaining participants' cultural perspectives and incorporating them into science programs in both formal and informal settings. In the informal science world, Aghasaleh et al. (2018) comment upon validating participants' rights to their own worldview as a way of building the trust needed for the successful transfer of AS&C. For example, when the Latinx youth in one of the groups used the title "F*ck Trump" for their computational problem-posing project, instead of reprimanding them, program educators probed them and suggested they include their rationale in their project.

Critique of Discourses of Power. Aronson and Laughter (2016) describe the Critique of Discourses of Power (CDP) as "culturally relevant educators explicitly unmask and unmake oppressive systems through the critique of discourses of power. Culturally relevant educators work not only in the classroom but also in the active pursuit of social justice for all members of society" (p. 167). Some researchers engage participants in culturally relevant science by addressing issues of social justice. Often these studies used culturally relevant tenets to design programs, support theoretical frameworks, and propose novel pedagogies (Brown et al., 2020; Djonko-Moore et al., 2018; Leonard et al., 2016; Morales-Doyle, 2017). For example, Brown et al. (2020) explained how they integrated virtual reality (VR) with CRP:

> The design elements of the CRP-VR lesson incorporated the flexibility of the VR platform with CRP tenets that purposefully catered to the ways in which students experience the world outside-of-school (i.e., visual, audio, and linguistic cues), thus bringing their culture inside the science classroom in a lesson aligned to the Next Generation Science Standards. These design elements contextualized the content in students" local communities and leveraged the opportunity to have students apply their learning within the VR lesson to these locales in ways that emphasize the fostering of a socio-political consciousness. (p. 89)

Utilizing virtual reality platforms to build politically conscious youth while at the same time meetings science standards is an excellent example of the combination of CDP and AS&C markers of CRE.

When CRE is applied to issues such as climate change, Djonko-Moore et al. (2018) proffered that politically conscious youth become warriors for environmental justice:

> Through culturally relevant experiential education in the form of science lessons in community-based centers and outdoor education settings, the children used science processes (i.e., observation, prediction, inference, problem solving, drawing conclusions, etc.) as they explored and collected data to learn about the environment, climate change, and sustainability. (p. 138)

Unmasking and unmaking systems of science oppression were anecdotally described when Leonard et al. (2016) presented the change of mindset that occurred in a White scientist after an interaction with students of color:

> The White male geologist and some members of the research team also learned from the students. At the outset, the geologist was wary about teaching climate change and taking urban students on field trips. At the end of the study, he and another member of the research team confided the students were very bright and well mannered. Their private comments reveal that engaging in equitable science teaching challenges assumptions about urban students of color. (p. 375)

Leonard et al. (2016) used this example to make the point that "changing teacher perceptions about students of color is critical to engaging them in high-quality science curriculum" (p.375). Morales-Doyle (2017) followed up on this point a year later noting in their section on implications for educational researchers that:

> Science teachers enacting justice-centered science pedagogy in different contexts would contribute a great deal to our understanding of how to address the seemingly intractable problem of inequity in science education. A second related line of research would examine the preparation of justice-centered science teachers and the development of in-service teachers as they gain experience with justice-centered approaches. (pp. 1056-1057)

Critical Reflection. Aronson and Laughter (2016) describe Critical Reflection (CR) as when "culturally relevant educators engage students in critical reflection about their own lives and societies. In the classroom, culturally relevant educators use inclusive curricula and activities to support analysis of all the cultures represented" (p. 167). Both Brown et al. (2019) and Rodriguez (2015) developed courses to help teachers understand CRP and learn how to enact it in their classrooms. Hansen et al. (2019) expounded upon the culture of the classroom to help teachers reflect on their role in establishing inclusive or exclusive environments:

> For example, in the traditional classroom, rules might consist of staying seated in a desk and paying attention to the teacher who is primarily stationed at the front of the room. If a teacher has also created the norm that a student must raise her hand to speak, whispering to a neighbor is then view as breaking a rule. If children are reprimanded for talking out of turn, this then reinforces and upholds the culture of the classroom. (p. 99)

Bottoms et al. (2015) provided opportunities for their pre-service teachers (PSTs) to reflect critically on their lives and their role in society by connecting culturally relevant theory to practice within their classrooms. They supported PSTs in the development of culturally relevant science tools and practices. Bottoms et al. (2015) stressed the importance of flexibility and the need for PSTs to "improvise and adjust on a moment-to-moment basis" (p. 733).

Like Bottoms et al., Brown et al. (2019) also “blended theoretical foundations of culturally responsive pedagogy with practical applications in science-specific contexts, (p. 30) while asking teachers to reflect on the contexts of their lessons and cultural appropriateness of their lessons. The research team used the Culturally Responsive Instruction Observation Protocol (CRIOP) (Powell & Rightmyer, 2011). Rodriguez (2015), on the other hand, used a single case study of Gary, to describe a White male teacher’s ability to critically reflect on his classroom practices resulting in increased involvement and academic achievement by his students and praise from his colleagues. The two studies that focused on Indigenous participants (one formal and one informal) also utilized CRP in the development of their programs and lesson plans. Miller and Roehrig (2018) reported positive outcomes from a student lesson that incorporated the guidance of the wider community. In this case, critical reflection occurred among all participants, with the students, teachers, and community constructing personal connections to the culturally relevant science activity. Littrell et al. (2020) also presented findings that support the use of CR in helping Indigenous youth learn science.

Cultural Competence. Aronson and Laughter (2016) describe Cultural Competence as “Culturally relevant educators facilitate students’ cultural competence. The culturally relevant classroom is a place where students both learn about their own and others’ cultures and also develop pride in their own and others’ cultures,” (p. 167). Several informal studies used culturally relevant science as a foundational principle of their community-based science program and as a framework for program models and evaluation design. It was interesting to see Augare et al. (2017) utilize CRE for designing program evaluations. McRae (2018) presented a strategy of beginning with a “cross-cultural science unit with a clear indigenous knowledge framework outlining key concepts, ideas, and values first, after consultation with local indigenous elders, as well as specifying the Western science foci," (p. 50). This strategy ensured that the participants learned about and celebrate both their own culture and others' culture, which Aronson and Laugher (2016) list as the definition of the CC marker.

Between 2015 and 2020, CRE has been conceptualized in formal and informal science literature as primarily a framework for developing youth programs and teacher trainings. A few articles step outside of this trend, for example, Dupuis and Abrams (2017) report on CRE used in standardized testing, Morales-Doyle (2017) incorporated CRP a priori codes in support of a new proposed justice-center pedagogy, and Augare et al. (2017) developed evaluations. However, for the most part, CRE literature advanced understanding in the science education field predominantly through formal programs.

Adapting Culturally Relevant Education for Science in Informal Settings

The majority of existing literature on educators' use of CRE focuses on formal education (Brown, 2017; Kudumu, 2021). Furthermore, empirical articles that demonstrate how DEI has been defined in ISE tend to report using CRE or associated pedagogies in program development or as foundational theory (Brown et al., 2019; Kudumu, 2021). These studies primarily adopt a descriptive study design, describing investigations that involve youth participants, as ISE institutions have often been seen as the domain for children (Ruffo, 2013). Very few of the papers investigated multigenerational communities and none of the literature focused solely on science center educators. What can be clearly stated is that CRE has been useful in formal settings and a case can be made for its potential usefulness in informal settings (Brown et al., 2019). In this study, I modified the CRE framework described by Aronson and Laughter (2016) to informal science specifications and utilized the framework to explore science center educators' perceptions of cultural relevance in science centers. The modification of the CRE framework to ISE settings holds the promise to help science centers become what they strive to be—multicultural, multi-lingual, multigenerational places of science enthusiasm, science interpretation, and science popularization.

Djonko-Moore et al. (2018) point out that “science educators and scholars have come to realize that science instruction is often disconnected from the lives of students [and therefore] science should be presented in a manner that considers diversity and inclusion of underrepresented persons, community-based issues, and other cultural aspects,” (p. 139). Weiland (2015) sought to discover how science centers could offer culturally sustaining experiences for Hispanic mothers as they visited with their children. She found that because informal science learning is seen as a cumulative sociocultural process (Rennie, 2014) it can validate the sociocultural identity of both adult and children learners (Weiland, 2015). While the outcomes of culturally relevant experiences in ISE institutions have been under-researched, it is clear that connections drawn between science concepts presented in exhibits and the everyday lives of people from diverse communities lead to greater group interactions (Weiland, 2015). Although several researchers suggest that African Americans do not always feel comfortable in ISE learning environments due to the lack of social and racial acceptance associated with these institutions (Dawson, 2014b; Dudzinski, 2011; Philipp, 1999), ISE activities are still deemed important for African American children by their families.

Falk and Storksdieck (2005) reported that adult learners are influenced by their concepts of themselves, their personal and sociocultural context, and the “vibe” of the learning environment. Culturally relevant and responsive frameworks place learners at the center of instruction and allow the blending of family culture with the current context of the museum experience. Using culturally relevant principles to evaluate the group social interactions of families visiting science centers recognizes parents' cultural capital, positions parents as intellectual resources, and respects the dynamic roles adult family members play in informal STEM learning. While observing science center conversations, researchers found that families used dialogic inquiry in which parents asked and answered questions, as well as probed children for observations and interpretations, in order to explain and make sense of science exhibits (Zimmerman et al., 2009).

CRE can take into account the social resources, such as cultural tools, used by families as they explore science exhibits. Zimmerman et al. (2009) defined these "cultural tools" as the ways in which families communicate, interpret, and absorb knowledge, as well as the ways in which they utilize resources, from artifacts to their worldview, in their interactions. With culturally relevant and responsive theories, researchers can examine the alignment of the museum experience with the sociocultural context of African American, Hispanic, and other under-served families while uncovering the social resources and cultural tools that these families utilize in group interactions as they explore informal science exhibits with their children.

Another notable characteristic commonly found in the literature was the concept of teachers as cultural brokers that needed to acclimate to the students' context, teach the whole child and the whole class, and model justice-centered science (Brown, 2017). The discourse in peer-reviewed literature between 2015 and 2020 on DEI in ISE institutions revolved closely around broadening the participation of people of color (Kudumu, 2021). On the other hand, literature on formal science settings from the same period emphasized preparing teachers to be critically reflective and culturally competent in the face of linguistic and cultural challenges (Aronson & Laughter, 2016; Kudumu, 2021). Educators from informal settings were rarely included in the investigations. It was heartening to have reviewed studies confirming that CRE, or associated pedagogies, are being incorporated into informal science program development. However, none of the program participants were science center educators. Furthermore, none of the participants were White, which further complicates the connection between science and White normativity. All of these issues are impossible to resolve with the relatively small number of research studies dedicated to this topic, thus further supporting the case for future investigations of CRE in informal science settings.

Summary of Chapter Two

This chapter reviewed the literature related to the culture of science, the beliefs of formal and informal science educators, and the theoretical framework modified for use in this dissertation study. Although Aronson and Laughter (2016), in their article, *The Theory and Practice of Culturally Relevant Education: A Synthesis of Research Across Content Areas*, reviewed journal articles on CRE in all academic disciplines that were published between 1995 and 2013, they only located five studies that were connected to science. In Brown's (2017) more targeted metasynthesis, she located fifty-two articles of empirical research studying cultural relevance in science education. However, only 8 of Brown's articles reported studies in informal contexts, and none of the 8 were located in a science center. All 8 of the informal studies reviewed by Brown (2017) were located in out-of-school settings such as afterschool programs and summer camps.

The development of a culturally relevant model that is applicable to informal science education settings is important to halt the further marginalization of communities that have been unable to access STEM opportunities (Dawson, 2014a, 2014b; Feinstein & Meshoulam, 2014; NCR 2009). Twenty-first-century science, as enacted in the US, is still presented as objective truth and void of culture. Meanwhile, every decision from the investigational direction, research questions, and methods, to data analysis is made by scientists who are cultural beings. This "hidden culture" of science can act as a barrier to access for some communities. CRE has evolved to address these issues across formal education content areas (Aronson & Laughter, 2016) and has more recently been applied to informal science settings. Hence, this literature review offers an opportunity to take a closer look at the potential benefits of CRE in informal science domains, supports the investigation of informal science educators' beliefs about culture and science, and at the same time, illuminates gaps in the research literature.

CHAPTER 3

METHODOLOGY

The purpose of this qualitative study was to learn what science center educators (SCEs) understand about CRE, think about cultural relevancy in informal science contexts, and describe as practices to apply culturally relevant principles in science centers. To achieve this purpose, the following research questions (RQs) guided this study:

RQ1: How do science center educators conceptualize cultural relevancy in informal science education?

RQ2: What are science center educators' perceptions of the role of cultural relevancy in science centers?

RQ3: What are science center educators' current practices related to applying culturally relevant principles in science centers?

Addressing the formulation of research questions, Creswell's criteria for question selection clarifies that qualitative research questions should be open-ended, evolving, and start with words such as 'what' and 'how' as opposed to 'why' (Creswell, 2007, p. 107). Creswell (2007) goes on to say that sub-questions help to break down the central research topic for closer examination. In this regard, research question 3 included the following two sub-research questions (SQs):

SQ3a: What are SCEs' perceptions of ideal practices to improve CRE in science centers?

SQ3b: What are SCEs' perceptions of supports for and barriers to applying culturally relevant principles in science centers?

The central research questions as well as the sub-questions supported the need in the ISE field to understand successful culturally relevant practices, which could be used to produce a tiered recommendation for their adaptation and adoption in more science centers.

Research Design

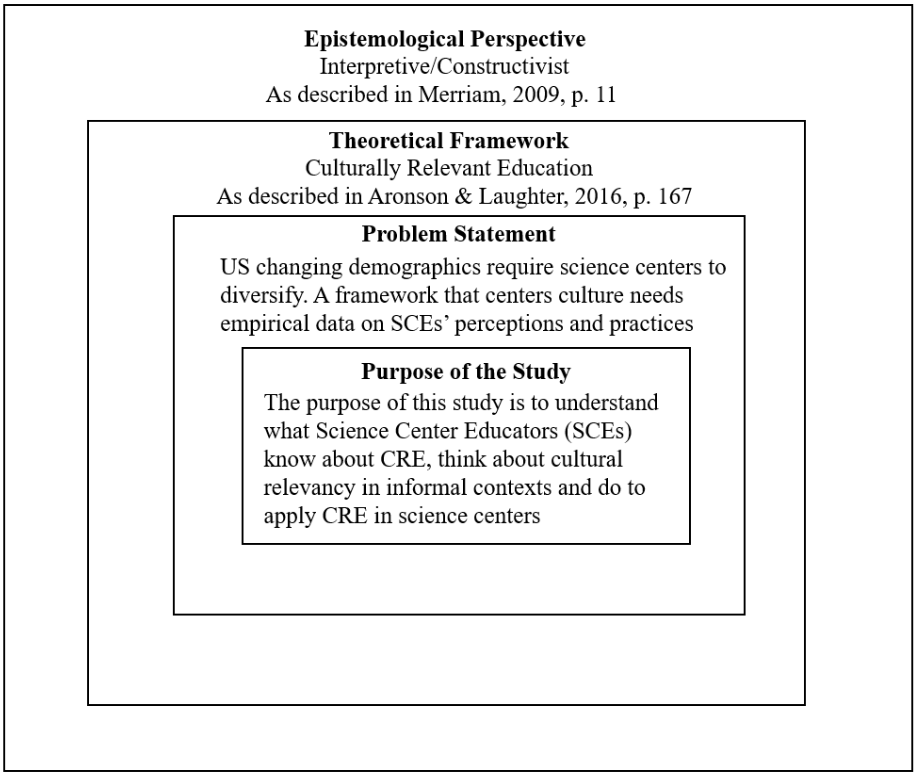
This dissertation research utilized a basic qualitative approach (Merriam, 2009; Merriam & Tisdell, 2015; Patton, 2002) to uncover and interpret science educators' perceptions and applications of CRE as they worked in informal settings. The epistemological perspective that functioned as the underlying philosophy of this study was interpretive constructivism, which seeks to describe, understand, and interpret phenomena (Merriam, 2009). A qualitative design offers an opportunity to provide in-depth descriptions of participants' experiences and outlooks, leads to a deeper understanding of the process, and can ultimately influence practices and policies (Creswell & Poth, 2018). According to Merriam (2009), basic qualitative research is the most common approach used in educational research. It is flexible, interpretive, and "seek[s] to discover and understand a phenomenon, a process, or the perspectives and worldviews of the people involved," (Merriam, 1998, p. 11); therefore, this approach is ideal for addressing research questions centered on participants' perspectives.

Interviews and observations are the primary instruments of data collection in basic qualitative studies, as the purpose is to understand "how people make sense of their lives and their experiences," (Merriam, 2009, p.23). Usually, a relatively small number of purposively selected individuals participate in basic qualitative research, given that the primary focus of the study is meaning and understanding (Merriam, 2009; Patton, 2002). Using an inductive comparative method, data analysis in basic qualitative research allows the investigator to synthesize concrete data into conceptualized categories of meaning (Merriam, 2009). Ultimately, findings from basic qualitative studies are richly descriptive representations of recurring patterns, themes, and categories (Merriam, 2009).

By using basic qualitative methods to explore the perceptions of science center educators, this dissertation provides detailed insight into their lived experiences and perspectives of CRE as they navigated through the nuances of their DEI-related responsibilities. It was not the goal of this study to predict or hypothesize about informal educators' beliefs about CRE, as the results of a quantitative study might provide (Caelli et al., 2003; Merriam & Tisdell, 2015). Neither was the goal to make sweeping generalizations about this specific population (Creswell & Poth, 2018). Rather, the purpose of collecting this qualitative data was to dive deep into the worldviews of the participants in order to develop rich characteristics of CRE in informal contexts and to offer the field recommended practices and ideas on how best to support people working in these positions. Furthermore, the guiding theoretical framework of this research was Culturally Relevant Education (CRE) because of its emphasis on the perceptions and practices of the educator (Aronson & Laughter, 2016); thus, using a basic qualitative study design provided an opportunity to apply this analytical lens to informal contexts. Adapted from Merriam (2009, p. 68), Figure 3 details the epistemology, theoretical framework, problem statement, and purpose of this study. Interpretive Constructivism, described by Merriam (2009) as seeking to describe, understand, and interpret phenomenon, was the epistemological foundation of the study. CRE as described by Aaronson and Laughter (2016) and modified by the author (Kudumu, 2021) for use in ISE, operated as the Theoretical Framework that guided the study. The problem identified by the study was the need for empirical data regarding the usefulness of a culturally centered critical education framework to address the DEI challenges of science centers. The purpose of the study was to understand what SCEs know and think about CRE.

Figure 3

Epistemological and Theoretical Viewpoint of the Study



Note. Adapted from *Qualitative Research: A Guide to Design and Implementation* (3rd ed.), by S. B. Merriam, 2009, p. 68, Jossey-Bass. Copyright 2009 by Jossey-Bass.

Context

The context for this study is science centers located across the continental US. Rennie (2014) used the term *museum* to describe all informal science education (ISE) institutions. However, this study uses the term *science center* to reflect aquariums, botanical gardens, interpretive science and technology centers, planetariums, science museums, and zoological gardens (Rennie, 2014). According to ASTC, the mission of science centers is to "increase[e] understanding of and engagement with science and technology among all people [by] support[ing] lifelong science learning, connect[ing] science and society, engag[ing] diverse communities, [and] partner[ing] to tackle global and local challenges" (ASTC, 2022).

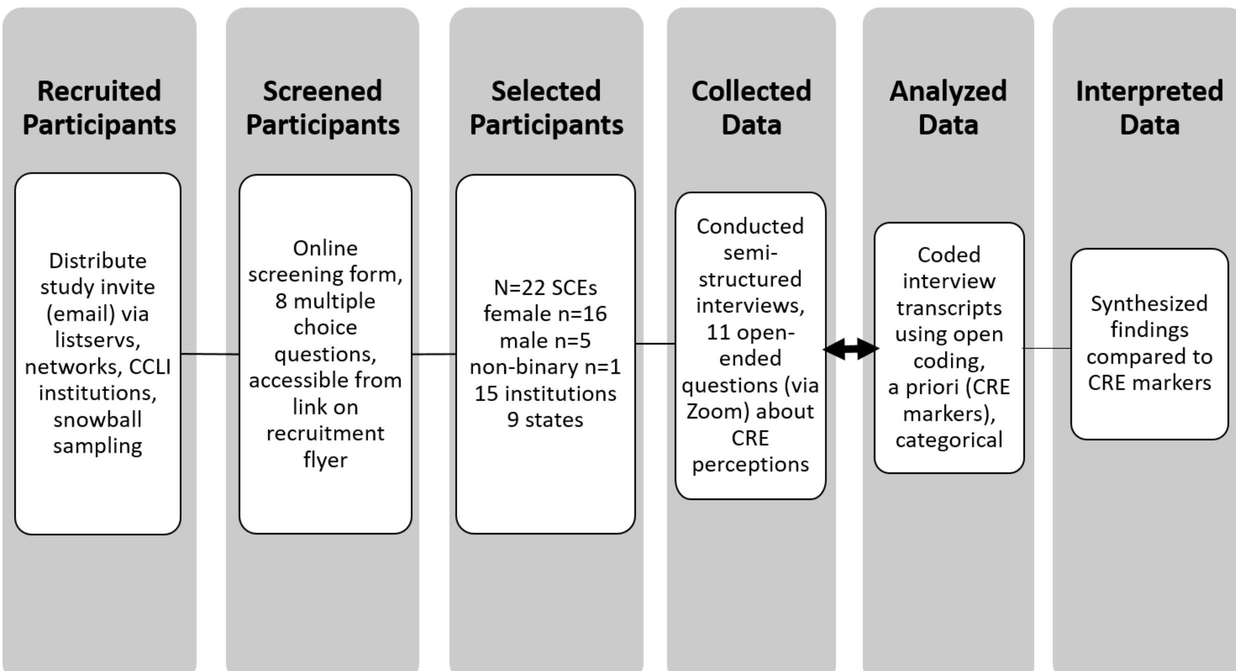
The 15 science centers that provided the context for this study are located in nine states, dispersed throughout four regions, and represent three time zones in the continental US. They are a mixture of aquariums (2), interpretive science and technology centers (4), science museums (6), combined history and STEM museums (2), and a science-focused children's museum (1). These medium to large-size institutions have annual budgets that range from under 5 million dollars (5) to between 5 and 20 million dollars (6), and greater than 20 million dollars (4). Most of the participants described their institutions' commitment to DEI as 'moderately committed' (54.5%) to 'very committed' (36.4%) and only two participants (9.1%) described it as 'not very committed'. None of the participants felt that their institution was 'very successful' in its DEI practices, rather, the majority felt they were 'moderately successful' (81.8%) while a few (18.2%) went as far as to say they were 'not very successful'.

Research Procedures

In order to understand the potential barriers that science centers face when attempting to provide more inclusive environments, it is useful to describe what educators working in these spaces experience as they engage with DEI practices at their science-related institutions and to study their processes of making sense of these experiences. The assumption behind this research approach is that by conducting in-depth interviews with 22 individuals from different science centers, essential themes can be synthesized that represent participants' meanings (Creswell & Poth, 2018). It is worth noting that qualitative research is also concerned with the discrepancies found in data that illuminate a unique experience or perspective (Merriam, 2009). However, basic qualitative studies characteristically result "in identification of recurring patterns, categories, or factors that cut through the data and help to further delineate the theoretical frame" (Caelli, et al., 2003, p. 6). In other words, for this study, the commonalities that exist between the experiences of science center educators can offer insight into ways science centers can become more inclusive of diverse communities. Figure 4 details the research procedures conducted for this study, which included collecting, analyzing, summarizing, and interpreting data using qualitative techniques.

Figure 4

Research Procedures



Participant Recruitment. A snowball sampling method identified a pool of informal educators working at science centers located within the US. Snowball sampling is a non-probability recruitment technique in which research participants who meet eligibility criteria help to recruit other participants who in turn recruit additional participants (and so on) by reaching out through their professional and social networks (Levine, 2014; Merriam, 2009; Patton, 2002). In addition to the snowballing method, a study recruitment email was distributed directly to staff in the education, exhibits, members' services, and administrative departments at science centers that participated in the Cultural Competency Learning Institute (CCLI) Landscape Study of Diversity, Equity, Accessibility, and Inclusion (DEAI) Practices in Museums (Garibay & Olson, 2020). See Appendix A for a list of science centers that participated in the CCLI study. I also distributed the study recruitment email via listservs hosted by professional networks (e.g., ASTC, NARST, and Association of Zoos and Aquariums) and through my personal connections.

Purposeful sampling, also known as criterion sampling, is a design strategy where research participants are selected according to prescribed criteria because of their knowledge of and/or proximity to the phenomenon under study (Patton 2002). These participants are specifically chosen because they are what Patton (2002) refers to as "information rich." As is recommended for most qualitative studies (Denzin & Lincoln, 2000; Patton, 2002), participants in this study were selected through purposeful sampling (McMillan, 2008). Science center staff interested in participating in the study completed a screening survey accessible through a website link included in the study recruitment email. The 8-question screening survey found in Appendix B included eligibility criteria questions to aid in participant selection. Although 65 individuals accessed the screening survey, 11 did not respond to any of the questions and one was a duplicate, Participants were purposefully drawn from the pool of 53 respondents, using the participant selection criteria to increase the likelihood of understanding the phenomenon under study.

Participant Selection Criteria. Researchers differ on the number of participants necessary for a basic qualitative study, with literature citing as few as 5 (Creswell & Poth, 2018) and up to 50 (Dworkin, 2012). However, many educational researchers agree that the concept of reaching saturation, the point where no new data is collected, is the critical factor for deciding sample size (Creswell & Poth, 2018; Dworkin, 2012; Merriam, 2009; Patton, 2002). The goal of this study was to include participants representing a mixture of experience levels, types, and sizes of organization, races and ethnicities, genders, and organizational commitment to DEI. Given that the study investigated the conceptualizations, perceptions, and practices of CRE by science center educators, the selection criteria included individuals who:

- Worked at a science center (either science museum, zoo, botanical garden, aquarium, planetarium, interpretive science and technology center, or children's museum with a science focus) in the US
- As a regular part of their job, educated audiences either in-person or through program and/or exhibit development
- Employed DEI practices at their institution
- Consented to participate in a 45 minute to 1-hour long videoconference interview

While participants were not intended to represent the experiences of all science center educators, by purposefully selecting diverse candidates from within the recruitment pool, the shared experiences of the study participants revealed the essence of the SCEs perceptions and practices regarding cultural relevancy.

Participants

The term "science center educators" (SCEs) was used broadly in this study to describe staff that "either explicitly through the in-person implementation of a program, or implicitly through the design of an exhibit or program," are responsible for educating audiences in science centers (including staff from public programs, education, visitor services, animal husbandry, and exhibits departments) (Busch et al., 2022). Similar to the demographics of the field (AAM, 2022), participants (N=22) were predominantly White/European Ancestry 72.7% (n=16) and

95% (n=21) had over three years of experience working in ISE. Of the 22 SCEs that participated in this study, the majority, 72.7 % (n=16) were female, 22.7% (5) were male, and one (1) identified as non-binary. Although the participants were primarily from the White/European Ancestry race (72.7%), there were five (22.7%) Black/African Ancestry participants and one mixed race participant. None of the participants identified as ethnically Hispanic.

Table 2

Participant Demographics

Pseudonym	Gender	Race	Years of Experience
Alina	Female	Mixed Race: Native and White	More than 20 years
Anne	Female	White or of European ancestry	6-10 years
Bekka	Female	White or of European ancestry	11-20 years
C. Harding	Female	White or of European ancestry	11-20 years
Carmen	Female	Black or of African ancestry	6-10 years
Catherine	Female	White or of European ancestry	6-10 years
Cindy	Female	White or of European ancestry	More than 20 years
Dio	Male	Black or of African ancestry	3-5 years
Donald	Male	White or of European ancestry	3-5 years
Emily	Female	White or of European ancestry	3-5 years
Frank	Male	White or of European ancestry	3-5 years
George	Male	White or of European ancestry	11-20 years
Helen	Female	White or of European ancestry	11-20 years
Ir	Non-binary	White or of European ancestry	3-5 years
Kristy	Female	White or of European ancestry	6-10 years
Lucy	Female	Black or of African ancestry	3-5 years
Marie	Female	White or of European ancestry	11-20 years
Rose	Female	Black or of African ancestry	6-10 years
Sara	Female	White or of European ancestry	Less than 3 years
Shawn	Female	Black or of African ancestry	11-20 years
Sven	Male	White or of European ancestry	11-20 years
Trish	Female	White or of European ancestry	11-20 years

The participants represented a range of experience working in ISE settings, with only one participant working for less than three years in the field. Almost all of the participants 77.3% (n=17) worked in the Education Department. Table 2 details the participants' demographical information excluding place of work to maintain participant confidentiality.

Data Collection

Two different sources of data were collected: screening surveys and interviews. The primary data for this study was semi-structured interviews, which are the most common data collection technique used for the basic qualitative approach (McMillian, 2008) and is in keeping with the tenets of basic qualitative research (Creswell & Poth, 2018; Merriam, 1998). Patton (2002) details three types of qualitative data: "in-depth, open-ended interviews, direct observations, and written documents," (Patton, 2002, p. 4). While many basic qualitative studies also incorporate observations (Creswell & Poth, 2018), the social-distancing restrictions in response to the COVID-19 pandemic prohibited in-person observations of DEI practices and hindered the collection of documents at the time of data collection. However, peer review and member checking were used to strengthen the trustworthiness of the interpretation of the participants' experiences. All data was stored in a password-protected Google Drive folder in the university-supported cloud (to safeguard against possible computer failure and data confidentiality breach). Table 3 describes the collection instruments, collection methods, and analysis used for each type of data collected.

Table 3

Data Overview

Data Type	Collection Instrument	Data Description	Purpose	Collection Method	Analysis
Survey	Qualtrics form questionnaire	Short, multiple-choice questionnaire as a screening tool; 12 questions (designed to ask questions from the study eligibility criteria)	Screening tool used to purposively select participants for the study from a variety of experiences, differently sized institutions, and range of success in their DEI efforts	web link	Used selection criteria a priori codes (e.g., to label institutional size, educator experience, and perception of DEI success) to categorize the responses to select a good mix of participants
Semi-structured interview	Interview protocol (questions, script and probes)	Interview transcripts Approximately 1 hour-long semi-structured interview; 12 open-ended questions reviewed by informal education researchers, dissertation committee members, and graduate student peers. The interview protocol pre-tested with 3 graduate student peers with science center experience.	Primary data collection source	Zoom	Used constant comparative method beginning with open coding to develop emergent codes, data was chunked then coded, codes were validated by graduate student volunteers conducting inter-rater reliability, coded data were categorized into themes related to the research questions; quotations drawn from the interview responses characterized the themes. Also used directed QCA approach with CRE markers as a priori codes

Screening Survey. Although some experts in social science (or educational) research design place questionnaires and surveys in the realm of quantitative research techniques, while considering interviews and observations as standard qualitative methods (Creswell & Poth, 2018; Merriam & Tisdell, 2015; Patton, 2002), Sharan Merriam (2009) noted that a highly structured interview is really a survey in oral form. Merriam goes further to state that "data from surveys on any number of topics — all can be treated as documents in support of a qualitative investigation," (p. 149). It was with this understanding that the study utilized an eight-question, open-ended survey as a screening tool to select 15-20 participants from a recruitment pool of informal science educators (see Appendix B for the questions and probes in the screening survey).

Interviews. The primary data collection tool for this study will be a semi-structured interview with questions, probes, and script based on constructs from the CRE framework (see Appendix C for the interview questions). Interviews are verbal conversations between researchers and participants that consist of open-ended, in-depth questions to solicit responses about the participant's thoughts, understanding, feelings, perceptions, and actions (Merriam, 2009; Patton 2002). They help the researcher gain a detailed understanding of the participant's perspectives, while also providing the opportunity for the researcher to probe and clarify this understanding with follow-up questions (Nelson & Cohn, 2015). Researchers utilize interviews to collect information from participants when observations are not possible or when the information needed is not observable (Merriam, 2009; Patton, 2002). Merriam and Tisdell (2015) describe the various types of interviews for example person-to-person, group conversations with pre-determined questions in a highly structured manner, loosely structured questions with probes delivered in a semi-structured interview, or completely unstructured exchanges. The data that results from interviews are direct, contextual quotations about the topic under study (Patton, 2002). For this dissertation study, I conducted semi-structured interviews, with selected science center educators (n=22), via the Zoom video-conferencing platform. The length of the interview was 45 minutes to 1 hour. The interview was video recorded and transcribed by the Zoom platform and verified and reconciled using my interview notes.

Interview Protocol Development. A number of the interview questions were adopted from a study by Brown et al. (2019) exploring the knowledge and application of culturally relevant education by math and science teachers from urban schools. The interview questions from this study were seen as valuable to the current study because they directly inquired about science teachers' perceptions of CRE. Questions from Brown et al. (2019) were modified to fit informal science educators, then tailored to address the research questions. Additional questions were added to give insight into participants' personal, educational, and professional backgrounds—detailing their journey to their current informal science education position. See Appendix D for a table pairing each component of the CRE framework with the interview question and corresponding research question (as well as interview tips, interview questions, probes for each question. etc.).

Although many of the questions were used in published studies (Brown et al., 2019; Busch et al., 2022), the modifications made to fit the population for this study, additional questions to better address the research topic, and revised question order for better interview flow, produced a new instrument worthy of expert review. Practitioners from the field, dissertation committee members, and graduate student peers conducted a cognitive content review of the interview protocol for clarity and usability. Prior to the use with study participants, the interview protocol was pilot-tested on graduate student peers with informal science education experience (Chenail, 2011; Merriam, 2009). The results from the cognitive review and pilot testing informed revisions to the interview protocol. The final interview protocol is found in Appendix C.

Data Analysis

The data analysis process followed standard analysis techniques for qualitative data (Caelli et al., 2003), and involved several stages of open, a priori, categorical, and emergent coding (Creswell & Poth, 2018), and included member checking to verify study findings (Merriam, 2009). The data set for this study consisted of responses to a screening survey as well as transcribed interviews (see Table 3 for the Data Overview). Participants chose a pseudonym that was incorporated into the file names for their transcript and screening survey. The data collected from each participant was stored in the Google Drive platform within the university-supported, password-protected cloud (to safeguard against possible confidentiality breaches or computer failure). Data were analyzed using the ATLAS.ti Web (Version 3.15.0-2022-03-09) to code 788 (N=788) quotes from 22 (N=22) transcribed interviews and to group topics thematically (ATLAS.ti, 2022). De-identified data were transferred into Microsoft Excel spreadsheets for sorting (to take advantage of the expanded search options) and then transferred back into Google Sheets for storage.

When drafting the analytical plan for this dissertation research, it was necessary to review the pros and cons as well as the similarities and differences of several qualitative approaches for data analysis. The study utilized a basic qualitative design gathering semi-structured interview data to provide a rich description of science educators' perceptions and practices of CRE. There is a good amount of overlap between methods of various qualitative analytical approaches and a shared goal to illuminate a phenomenon from the experiencer's perspective (Vaismoradi et al., 2013). Thus, it was necessary to consider the research questions when choosing the appropriate analytical approach. In order to address the research questions, participants were asked to elaborate on their views, understanding, and actions. These types of questions produced long interview transcripts, which required an analytical approach capable of handling copious amounts of textual data.

Merriam (2009) describes data analysis for basic qualitative research as usually inductive, comparative, and useful to create “common themes or patterns or categories that cut across the data,” (p. 269). Yet, the exploration in this study began with a theoretical framework. Therefore, it was both deductive, in that it aimed to investigate an existing theory (culturally relevant education), and inductive because it explored the application of that theory to a new context (science centers). The ideal analytical approach for this dissertation needed to be flexible, descriptive, and able to tackle voluminous data. Qualitative Content Analysis (QCA) was the approach that met those criteria, in that it allowed me to search for patterns and themes to create categories from pages of interview transcripts (Vaismoradi et al., 2013).

Three classifications of Qualitative Content Analysis. The literature on content analysis delineates three distinct classifications of qualitative content analysis (QCA)—conventional, directed, and summative (Assarroudi et al., 2018; Hsieh & Shannon, 2005). While similar in their aim to interpret meaning from text, the three are different in their methods of addressing coding and trustworthiness (Hsieh & Shannon, 2005). Codes and coding categories are extracted directly from textual data in conventional content analysis, while initial codes are derived from a theory in directed content analysis, and are keywords that are counted and compared in summative content analysis (Hsieh & Shannon, 2005; Vaismoradi & Snelgrove, 2019).

Threats to trustworthiness also differ for each type of content analysis and thus require different techniques to validate findings. For example, Hsieh and Shannon (2005) describe one of the challenges of conventional content analysis as overlooking key categories and therefore "failing to develop a complete understanding of the context," (p. 1280). To address this issue they recommended a number of techniques to establish credibility including prolonged engagement and negative case analysis. On the other hand, they suggested beginning data analysis by "highlighting identified text without coding might increase trustworthiness" for the directed content analysis approach which can be hampered by a strong researcher bias since it is tied directly to a theory (Hsieh & Shannon, 2005, p. 1282). For summative content analysis, which requires a demonstration of trustworthiness, they suggested expert validation or member checking (Hsieh & Shannon, 2005).

Directed Content Analysis. According to Assarroudi et al. (2018), "directed QCA is used to validate, refine, and/or extend a theory or theoretical framework in a new context," (p.53). Since the study relied upon an existing theory, CRE, as the theoretical framework to guide the analysis and discussion of findings, transcribed interview responses were coded using directed QCA techniques that identified patterns in the data and organized the information into core themes of meaning (Hsieh & Shannon, 2005; Mayring, 2015; Patton, 2002; Schreier, 2014). Table 4 details the adaptions I made to the CRE Marker Statements. By replacing formal education terminology with ISE terminology, I was able to adapt the contextual framing of the markers' descriptive statements. Substituting the terms 'students' with 'audiences' and 'classroom' with 'science center' allows educational researchers to explore the DEI efforts of science centers viewed through the lens of the CRE framework adapted to fit the ISE environment.

Table 4

Culturally Relevant Education Markers Adapted for ISE Institutions

CRE markers (Dover, 2013)	**CRE Statements** (Aronson and Laughter, 2016; p. 167) (adaptations made by Kudumu, 2021)
Academic skills and concepts (AS&C)	"Culturally relevant educators use constructivist methods to develop bridges connecting ~~students~~ **audiences'** cultural references to academic skills and concepts. Culturally relevant educators build on the knowledges and cultural assets ~~students~~ **audiences** bring with them into the ~~classroom~~ **science center;** the culturally relevant ~~classroom~~ **science center** is inclusive of all ~~students~~ **audiences**."
Critical reflection (CR)	"Culturally relevant educators engage ~~students~~ **audiences** in critical reflection about their own lives and societies. In the ~~classroom~~ **science center**, culturally relevant educators use inclusive curricula and activities to support analysis of all the cultures represented."
Cultural competence (CC)	"Culturally relevant educators facilitate ~~students'~~ **audiences'** cultural competence. The culturally relevant ~~classroom~~ **science center** is a place where ~~students~~ **audiences** both learn about their own and others' cultures and also develop pride in their own and others' cultures."
Critique discourse of power (CDP)	"Culturally relevant educators explicitly unmask and unmake oppressive systems through the critique of discourses of power. Culturally relevant educators work not only in the ~~classroom~~ **science center** but also in the active pursuit of social justice for all members of society."

The step-by-step procedures for data analysis followed the methods detailed in the article by Assarroudi et al. (2018). The authors described 16 steps organized into three phases (preparation, organization, and reporting). Steps 1-6 of the preparation phase of directed QCA (Assaaroudi et al., 2018), included acquiring general skills, snowball recruitment and purposive sampling strategy, the inclusion of both manifest and latent content, development of the interview guide, plan for interviews and transcription, and defining units of analysis. Step 7, data immersion, required reading and extracting the units of analysis N=788 (quotes from interview transcripts) multiple times to understand "'Who is telling?', 'Where is this happening?', 'When did it happen?', 'What is happening?', and 'Why?'" (Assaaroudi et al., 2018, p. 49).

Describing the process of coding using QCA, Hsieh and Shannon (2005) recommended that researchers develop a set of logical rules and procedures to systematically guide data analysis. These rules are called a *data analysis guide* or a *codebook.* Hsieh and Shannon (2005) noted “a good coding scheme is central to trustworthiness in research using content analysis” (p. 1286). I use the terms ‘codebook’ and ‘coding scheme’ interchangeably to describe the formative categorization matrix (Assaaroudi et al., 2018) that began with a priori codes from the CRE framework and was modified to add emergent codes from the participants’ statements. Steps 8-12 of the organization phase of directed QCA, focused on developing, defining, testing, and refining the formative categorization matrix (codebook).

Table 5

Codebook for RQ1: Science Center Educators Conceptions of CRE

Code	Description of Code	Category	Buzz words
Audience	Science center educators center the audience when they conceptualize cultural relevancy in informal science education.	audience	audience centered, being seen, community centered, connect to audience, learner's prior knowledge
Co-Development	Science center educators conceptualize co-development as a critical part of culturally relevant education.	co-development	co-development, tool kit
Culture	Science center educators consider culture as central to culturally relevant education	culture	culture centered, education for all, gender issues, inclusive, SCE's culture

Table 5, the codebook for RQ1, is displayed here as an example to illustrate the analysis process. The full codebook is in Appendix E. The codebook was developed following a deductive approach, created by the definitions of the main categories from the four markers of

CRE (Table 4), and an inductive approach—incorporated emergent categories from textual data. The coding rules were refined iteratively with the coding of each unit of analysis. The coding scheme was pre-tested using transcripts from pilot interviews with three graduate student peers. The anchor sample, the "explicit and concise exemplification, or identifier of a main category," was chosen concurrently with data collection, and refined during the study progression (Assarroudi et al., 2018, p. 50). Steps 13-15 detailed the quotes (meaning units) that were from the text, summarized, and ascribed preliminary codes. Generic categories were developed from preliminary codes that were grouped and categorized based on meaning, as well as similarities and differences. Finally, in step 16, the reporting phase, the report showed associations between the data and the CRE framework (Assaaroudi et al., 2018). The transcripts were cleaned to add punctuation, correct grammatical errors, and resolve any issues inherent from the Zoom transcribing process. The associated procedures conducted for this study are described in Table 6.

Table 6

Data Analysis Procedures

Phase	Step #	Directed QCA Step Description (Assaaroudi et al., 2018, p. 45)	Actual Procedures
Preparation	1	Acquired general skills	Examined relative literature, remained aware of my positionality, and reflected on epistemology, theoretical framework, problem statement, and study purpose
	2	Selected sampling strategy and criteria	Recruited snowball technique, purposively selected participants with study criteria
	3	Decided on the analysis of manifest and latent content	Developed analytical strategy for manifest content (actual text from interview transcripts) and latent content (interpretation of text, body language, and tone)
	4	Developed data collection tools	Developed and pilot tested screening survey questions, interview protocol, multiple choice questions, and probes (see Appendix D)
	5	Collected data: Conducted and transcribed interviews	Screened and selected participants using Qualtrics, Conducted semi-structured interviews, recorded, and transcribed via the Zoom platform
	6	Specified the unit of analysis	Quotations from interview transcripts were the units of analysis
	7	Became immersed in data	Read each transcript three times and contemplated who, what, where, and why
Organization	8	Developed a formative categorization matrix	(Inductive approach) Extracted emergent categories (Deductive approach) Created codebook from the four markers of CRE (see Appendix E)
	9	Theoretically defined categories	Used definitions of CRE markers to define the main categories
	10	Determined coding rules for categories	Detailed coding rules from CRE markers, refined coding rules iteratively
	11	Pre-tested the categorization matrix	Pre-tested codebook with peer review by dissertation committee Co-Chairs
	12	Specified anchor quotes for categories	Iteratively revised/refined anchor quotes with data collection and analysis
	13	Performed main data analysis	788 quotes (meaning units) selected from the text, summarized, and ascribed codes
	14	Inductive abstraction of main categories	Developed generic categories from codes, grouped and categorized by meaning
	15	Established links between categories	Compared generic and main categories, defined possible links, collapsed categories
Reporting	16	Reported all steps of directed content analysis and findings	Reported actual data collection, analysis process, finding, and data's association with CRE framework.

Ethical Considerations

Prior to launching the study, I submitted the study procedures, recruitment tools, informed consent form, data collection instruments, and interview script to the North Carolina State University Institutional Review Board (IRB) and received approval (eIRB# 24439). Prospective participants were informed during the recruitment process that the purpose of the study was to collect information about DEI-related responsibilities, accountability, barriers, and support in informal science institutions. They were asked to read an informed consent form and to give verbal consent during the recorded Zoom interview to signal their agreement to participate in all of the activities outlined in the form. The consent form explained that all personal and professional identifiers would be replaced with pseudonyms to protect the confidentiality of the participants, that there was no financial benefit for participating in the study, and that they had the ability to withdraw from the study at any time without question or consequence.

Research Credibility

The data was analyzed using ATLAS.ti and Microsoft Excel spreadsheets to code data and sort them thematically. I conducted all data collection and analysis activities and had coding consistency and accuracy of the coding scheme checked by graduate student volunteers independent to the research project. Inter-rater reliability (IRR) coding was performed to confirm the reliability of codes and definitions (Creswell & Poth, 2018). The codebook was tested by three graduate student peers through IRR of approximately 15% of the data (120 of the 788 quotes). The IRR produced an average of 87.95% agreement. After reviewing coding responses with the raters, we were able to reconcile the inconsistencies and come to 100% agreement. By applying "researcher's lens" strategies for validation as noted in the positionality statement, and collecting data from multiple sources (22 semi-structured interviews), efforts were made to substantiate the research findings. Finally, as a function of member checking, participants were solicited to provide feedback on study findings and interpretations by reviewing a preliminary draft of chapter four. Seven participants (32%) responded to the request for member checking. When asked to comment on whether the findings truly reflected their experiences in their DEI-related roles, 100% of the participants that responded confirmed that the findings and perceptions matched their experiences.

Positionality Statement

Creswell & Poth (2018) discuss the importance of the researcher revealing their personal biases to give the reader a clear understanding of the viewpoint from which the research was conducted. My experiences as an African American woman in higher education with leadership experiences in both the museum and corporate sectors likely influenced the design approach chosen for this study. As a former museum professional, I am keenly aware of the deficiencies of science centers in providing inclusive opportunities for diverse audiences. While planning this study and during implementation, I attempted to remain cognizant of my status as an "insider" member of the community from which the participants were sampled. I related to the participants because I have experienced the phenomenon of being tasked with the responsibility of ensuring more diverse and equitable practices at the ISE institution where I worked.

At the same time, the participants were made aware of my status as a doctoral candidate, researching their experiences in their science center educator roles. As a researcher peeking into their world, there was a possibility of a perceived division between the participants and myself that might have inhibited their ability to give forthright responses. As Ganga and Scott (2006) discovered, "Being insiders, paradoxically, raised researchers' and participants' awareness of the social subtleties that divide their respective … communities" (p. 8). I countered this paradox and encouraged participant engagement by developing semi-structured interview questions that were open-ended and free of academic jargon. In addition, I discussed the importance of the study with the participants and explained its potential to inform DEI-relevant practices at other informal science education institutions.

Methodological Limitations

There are limitations to conducting qualitative research at all stages—participant recruitment and selection, study context, and data collection, analysis, and interpretation. At each stage, these limitations, if not mitigated can be disastrous for the quality, legitimacy, and transferability of the research. Not enough participants, too narrow or too broad of a scope, inappropriate study design, data collection tools, and analysis techniques can all lead to reporting erroneous findings.

For example, at the data collection stage, there were limitations to conducting semi-structured interviews via Zoom. The platform did not offer the same opportunity for personal interaction, reading of body language, and setting of tone that in-person interactions provide. On the other hand, some benefits to using the platform included the free transcriptions and recordings of the interview, the ability of the participant to conduct the interview in the comfort of the location of choice, and of course the compliance with COVID-19 social-distancing restrictions. The length of the interview might have caused some participants to experience some fatigue and answer later questions with less enthusiasm and thoroughness than earlier questions. To combat this issue, I incorporated probing techniques to help keep the participant focused. Finally, as Garibay and Olson (2020) noted, studies on the topic of DEI are "vulnerable to social-desirability bias" (p. 11), which may tempt participants to give the answer they think should be given or that the researcher wants to hear. I also relied heavily upon follow-up probes to garner the trust of the participants and to encourage thoughtful honest responses.

The limitations caused by the COVID-19 pandemic required that all data collection occurred virtually via the Zoom platform. The opportunity to conduct a similar study with in-person interviews and observations of practice might shed further light on the possibilities of applying CRE or other formal education theories in ISE contexts. An in-person study would not only result in an extension of the current research, but it would also provide an opportunity to compare and contrast SCEs' conceptions of their culturally relevant practices to the actual observance of their practices. While the study design focused on SCEs from ISE institutions in the US, it is worth noting that several SCEs from science centers outside of the US expressed interest in participating in the research. Additionally, there was a notable lack of participants representing institutions from the middle of the country, the locations of the 15 participating institutions clustered on the edges of the US. Future studies with participants offering greater regional diversity could offer a deeper understanding of the application of CRE to support the DEI efforts of science centers both nationally and abroad.

Summary of Chapter 3

'Open-ended' and 'evolving' characterizes the three research questions that directed this investigation into the perceptions and practices of 22 SCEs' regarding cultural relevancy. The central RQs were further bolstered by two sub-questions aimed at taking a deeper examination of perceived supports and barriers to applying cultural relevancy in ISE institutions. Approached from the vantage of basic qualitative research design, this study employed semi-structured interviews conducted virtually via the Zoom platform, as the primary source of data. In addition to transcribed interviews, screening surveys, member checking of findings, peer review of thematic concepts, and inter-rater reliability coding were all employed to strengthen the validity of findings. Within this third chapter, the methodology, research questions, description of the participants and sampling procedures, data collection procedures and instruments, positionality statement, and data analysis procedures are given in detail. Participants, half of which identified as White females, represented 15 ISE institutions from across the US.

CHAPTER 4

FINDINGS

This basic qualitative research study examined informal science educators' conceptualization and enactment of culturally relevant education (CRE) in U.S. science centers. Themes developed through data analysis of interviews give greater insight into what science center educators (SCEs) know about cultural relevancy, what they think about the role of cultural relevancy in informal science education settings, and what they do to apply culturally relevant principles at the science centers where they work. The data also produced a list of ideal practices to improve CRE, as well as a list of barriers hindering the application of CRE in science centers.

In this chapter, I present findings in four subsections. The first three subsections explain each of the research questions for this study, explore the major themes that respond to the three research questions and sub-questions, and provide evidence to support the emerging themes in the form of quotes and comparison tables. The fourth section compares participants' conceptions and practices to the markers of CRE (Aronson & Laughter, 2016) to illuminate the extent of the application of CRE in science centers. Finally, the summary of this chapter provides an overview of what science center educators know, think, and do regarding cultural relevancy in informal science education institutions.

RQ1: Science Center Educators' Conceptualization of Cultural Relevancy

When investigating efforts to transform informal science education institutions into racially diverse, culturally inclusive, equitable spaces, it is helpful to understand what staff, who interact with the public at these establishments, know about the relevancy of culture to the enactment and interpretation of science, as well as to the public engagement and understanding of science. The first research question, "How do science center educators conceptualize cultural relevancy in informal science education?" considers how SCEs define the word "culture," explain the culture of the science center where they work, and describe their own culture. From the data analysis, three major themes arose regarding SCEs' knowledge about cultural relevancy: (1) that CRE is audience-centered; (2) that CRE centers culture; and (3) that CRE is reliant upon co-development.

When SCEs conceptualized cultural relevancy in informal science education they spoke of connecting to the audience, co-developing learning goals, and sharing decision-making. Participants in this research study conceived of CRE as audience-centered, inclusive, and incorporating the learners' prior knowledge. SCEs used the terms "democratic education" and "dismantling hierarchy" to describe the inclusive, education-for-all nature of CRE. Some SCEs found it difficult to describe CRE and were not sure what it would look like when implemented in informal science settings. Other respondents described the sense of belonging the audience feels when science programming centers culture. Still, a couple of participants warned of the pitfalls of enabling acronyms and cynically biased training.

Centering the Audience when Conceptualizing Cultural Relevancy

Findings showed that most SCEs, 86.4% (n=19) centered the audience when they conceptualized cultural relevancy in informal science education settings. SCEs recognized that as one participant named George phrased it "education is not a one-size-fits-all approach, so you are tailoring your content, but more so your presentation to the community that you're presenting to." Another participant, Sven, was very succinct in his explanation of cultural relevancy when he described that "the goal should be to provide a space where the educational experience embraces, supports, and connects to people's cultural perspectives." Participants spoke of making sure the content fits the audience's culture and "being attuned" to the audience. They conceptualized cultural relevancy as making sure that the audience feels seen and sees themselves reflected in the science, in the presentation, and in the ISE institution.

Making connections to the audience's life and worldviews were concepts that arose as participants discussed their knowledge of cultural relevancy in science centers. Another participant named Ir, described meeting "learners where they are to incorporate their broader worldviews and realities into the curriculum, to inform the direction of where the learning goes." Conversations about tapping into learners' prior knowledge and valuing non-dominant ways of knowing were also prevalent when SCEs discussed their conceptualization of cultural relevancy. Anne described cultural relevancy as taking "into account the existing knowledge, experience, and assets of the learner." Bekka expressed her understanding that "there are analogies and ways of knowing that are not acknowledged by the dominant system." However, she struggled to incorporate this understanding into her conceptualization of cultural relevancy without carefully defending her intentions by saying "I don't think I should just tap into it, but I think, I need to amplify it, to make it known. I do not want to say validate, because that sounds patronizing. Value! Yes, that is what I want to say."

SCEs, participating in this study, aligned their conceptualization of cultural relevancy with their audiences at ISE institutions by connecting science content to the audience, accessing learners' prior knowledge, and ensuring that audiences felt seen. However, they did not focus on the impact on the audience; rather, they emphasize the process rather than the product. When describing cultural relevancy in science centers, participants spoke at length about the process of focusing on the audience but did not mention what the outcome would look like. As they conceptualized cultural relevancy, SCEs painted a picture of ISE institutions trying to become more inviting to audiences and more responsive to their needs, yet it was an incomplete picture.

They did not add to their concept of cultural relevancy what the end product would be, they did not envision the inclusive science center. When probed for a description of what cultural relevancy would look like in a science center, several SCEs admitted that they could not “see it” or describe it. Donald, for example, said:

> I don’t know. I don't think I can give an answer. I know that we don't have a culture plan. I know that is something that we are working on. We actually have a meeting in two weeks to talk about what that looks like. (Donald’s Interview)

Bekka thought that she understood what cultural relevancy in science centers was supposed to look like, but she admitted that she would be “terrible at describing it.” Emily and Helen admitted that they had no idea what it would look like. The vision of the culturally relevant science center had somehow evaded SCEs’ conceptualizations. Ir described their inability to see the end product of cultural relevancy in this way “I think it's something that we like as an idea. It’s another one of those acronyms that enables us.”

Emphasizing “Culture” when Conceptualizing Cultural Relevancy

Throughout the interviews, 63.6% (n=14) SCEs consistently centered culture when conceptualizing cultural relevancy in informal science education settings. When defining cultural relevancy, they spoke of the importance of recognizing the audience’s culture when presenting programs and of incorporating cultural artifacts as a means to inspire greater public engagement in science. SCEs were aware of cultural differences between the communities that they served and those underserved by their institutions. Often times this awareness informed their conceptualization of cultural relevancy. Reflecting on her understanding of the term, Kristy noted:

> It is this idea that the standards of teaching were built around assessing the learning styles or assessing the family dynamics of a very limited range of people. There are cultural differences in the ways that people learn and respond to the educational systems. There are differences in the way that their culture taught them about the power structure and the roles of teachers. (Kristy's interview)

While some participants spoke of tapping into cultural identity markers to increase the presence of young Black students, others cautioned against stereotyping by adhering too closely to cultural assumptions based upon information from the past. Cindy, for example, advocated for "remembering that a culture isn't just its past, it's a living thing, it's something that's around today" in her conceptualization of cultural relevancy. Respect for other people's cultures and safeguarding against cultural appropriation, are concepts that SCEs explored. For example, Donald mentioned that he makes an effort to "be respectful to other's culture when conveying this education." He said that he "would never want to appropriate someone else's culture while trying to educate on a topic."

Participants also described the influence of a democratic culture that champions the concepts of education for all and therefore science for all. "Science is everywhere and science is for everyone," according to George, who also clarified that "the goal is to make education work for everyone, but, more specifically, work for people that it historically has not." SCEs incorporated the democratic cultural concept of inclusion when describing cultural relevancy in science centers. Democratic culture was seen as essential because of its theoretical opposition to exclusion. Bekka noted:

> It cannot be for all if students are outside of the experience because they are not connecting to the experience. I would think that the goal would be to truly have the

> democratic education that we claim to have. If we are of that belief system, that education is from democratic principles, and not just reproducing social workers or whatever those other theories of education are. (Bekka's interview)

Echoing Bekka's response, Ir clearly and succinctly stated, "The purpose of this type of learning is to take apart the structure of this hierarchy".

SCEs conceptualized the use of inclusive language, particularly inclusive pronouns, as they contemplated the concept of culturally relevant education in science centers. For example, one participant, Donald described "establishing that kind of framework of how to be inclusive…you need to ask, don't assume" the pronoun in which the person wants to be referred. Donald so closely tied his understanding of cultural relevancy to the open use of pronouns that he claimed, "I feel like it's been the most inclusive year that we've had, honestly just from something as small as asking people what their pronouns are." Another participant, Cindy, emphasized the use of inclusive language and described including everyone by "not talking about *them* so much as *us*." She took the 'we are all humans' approach, focusing on our humanity when she conceptualized cultural relevancy. "Everyone wants food, shelter, social group answers," she said as she centered her response on the culture of being human.

While SCEs considered culture as central to culturally relevant education, they often did not readily begin with recognition of their own culture's role in CRE. When asked to describe the culture of their institution, participants spoke at length about the nuances of their place of work. They painted an image that included basic demographics, hierarchical politics, mission-driven atmospheres, and supportive networks of like-minded people fueled by their mutual love for science. When asked to define "culture," participants easily answered with textbook-worthy, anthropological definitions of the term. However, when asked to describe their own culture, many of the respondents were flummoxed. Several participants noted that it was the first time someone asked them about their culture.

Table 7

Examples of Participants' Cultural Identity Trends

Participant's Pseudonym	Description of Own Culture	Own Culture Category
Dio	"I am a black American male raised in and have lived in [the southeastern US] my entire life and so I have lots of southern roots Black culture growing up in a Black churches"	Comprehensive - Race
Marie	"My personal culture? How do I describe my own culture? Um, it's interesting, I've never particularly thought about"	None, uncertain, or ambivalent
Catherine	"I come from very White America, Midwest White America, but also very poor group of family, so I have seen some of the struggles of the families that I work with"	Comprehensive - race & SES
Bekka	"As an individual I'm not sure I necessarily have culture. I reflect on the fact that I don't really have a strong culture identify, how would I identify with students or visitors if they have strong cultures?"	No culture but an epiphany
Ir	"The culture that shapes me is whiteness. I believe that American culture in general is a culture of White supremacy. I feel like as a White person, white is not an ethnicity, it's a cultural blob.	White supremacy

Table 7 displays some of the responses given by participants to the question "How would you describe your own culture?" These responses are organized into the following categories: comprehensive (race-related), none/uncertain/ambivalent, comprehensive (race and SES-related), no culture but an epiphany, and White supremacy (awareness of the complications of identifying with White culture). An expanded table comparing examples of participants' responses to questions about their definition of culture and their institutions' culture versus their own culture is located in Appendix F.

After further probing, a few participants incorporated checking their own bias in their understanding of cultural relevance. When probed about their own culture's influence on their concept of cultural relevancy, Ir responded, "Sure, I think it's about trying to, as an educator, you're starting by identifying kind of your own bias and your own cultural framing." Analysis of responses to questions about culture illuminated trends that at first glance seemed to fall along racial and socioeconomic lines. For example, when participants were asked to describe their own culture those that self-identified as Black or African American gave comprehensive descriptions that included their race, religion, location of rearing, as well as cultural morals, social norms, and values often attributed to many African American/Black communities. For example, Dio's responded:

> I am a Black American male raised in [the southeastern US] and have lived in [the south] my entire life. I have lots of southern roots, Black culture, growing up in Black churches, and it has informed a lot of facets of my life. (Dio's Interview)

On the other hand, many participants that self-identified as White or European American were caught off guard by the question, some expressing surprise, some uncertainty, and others admitting that they did not consider themselves to have a cultural identity. Baffled, Marie exclaimed "My personal culture? How do I describe my own culture? Um, it's interesting, I've never particularly thought about it." Sara, also initially surprised by the question, could not describe a culture that she identified with. Instead, she said:

> Goodness, I do not know. As a White person, I don't think that there is, inherently, a White culture. Other than that of maybe how we trace back our ethnicity. But, for me personally, no I don't define any of those things as a part of my particular culture. (Sara's interview)

However, White participants that described themselves as growing up poor or lower middle class, were unfazed by the question. In addition to their low socioeconomic status, these participants also identified their race, religion, and location of childhood. One of the participants in this category, Catherine, described her cultural identity by saying:

> I come from very White America. Midwest, White America. But, also from a very poor family. So, I have seen some of the struggles of the families that I work with. While I have the advantages of being White, CisHet female, I also came from a very poor family. We received free lunches growing up and struggled in that way. (Catherine's interview)

Two White participants had responses that stood out from the others. While Bekka admitted she did not consider herself to have a culture, when responding to the question she had an epiphany about how her lack of cultural identity could impact her connection with audiences at the science center. She explained that,

> As an individual, I'm not sure I necessarily have culture, because I think culture is built from Community. This is a hard question but I like where you're going with it. I am reflecting on the fact that I don't really have a strong culture that I identify with, so then, how would I identify with students or visitors that I work with if they have strong cultural identities? (Bekka's interview)

Meanwhile, Ir was never in doubt about their cultural identity. Without hesitation, they responded:

> That's a great question! The culture that shapes me is Whiteness. I believe that American culture, in general, is a culture of White supremacy. I feel like as a White person, White is not an ethnicity, it's a cultural blob. I feel like in America, we have an idea of what

White culture is and it's this kind of big hegemonic idea that's based on power more than it is on the history of a particular region. (Ir’s interview)

While over half of the SCE interviewed emphasized culture when conceptualizing cultural relevancy, they did not all reflect critically on their own cultural identity.

Co-Development is Critical when Conceptualizing Cultural Relevancy

In addition to focusing on the audience and centering culture, SCEs spoke about co-development when they explained their understanding of cultural relevancy. Over half of the SCEs, 54.5% (n=12), recognized the importance of working cooperatively with their audiences during the process of learning science. They understood it to be integral to their institution’s mission of interpreting science for the public. In order to engage audiences, participants often spoke of co-developing learning goals when describing cultural relevancy in science centers. Kristy, for example, discussed “finding ways of tailoring your practice to create spaces for you to receive feedback and co-create these structures.” Another example of co-development offered by participants was the engagement of audiences in the creation of behavioral norms and guidelines. In that vein, Ir explained, “I think one of the aspects is like the shared community guidelines we create. On the first day of this camp, we're doing a class culture contract creating guidelines together. Co-creating with learners the behavioral norms for the classroom.”

Participants wanted their audiences to feel a part of the science center and linked to the science content shared. Anne spoke of these connections between the institution and the community. She wanted “to see explicit connections like here’s the scientific topic [and] here are some different things that are happening in the community, that we learned about from the community that connect this scientific topic in action.” Anne recognized “co-development” as a buzzword being used in the field, but she maintained her belief in the importance of science centers working with the community. She wanted to demonstrate “that this educational product wasn’t just developed in isolation, by ‘educators’. That they really were talking to the learners in the community about what matters to them.”

When science center educators conceptualized CRE in informal science education, they sometimes spoke of tools such as scripts and program outlines. These tools can be considered either a help or a hindrance to co-development and sometimes they are considered both. SCEs like Kristy found the tool belt imagery helpful when conceptualizing cultural relevancy. Kristy said:

> I use the metaphor of a tool belt because when you get a bigger tool belt you realize that they're different tools that you didn't even think about using. I think of doing culturally relevant education, being able to completely change my approach and being responsive based on this really important tool. (Kristy’s interview)

Nevertheless, several participants pushed back on the notion of cultural relevancy as a tool. Sara, for example, noted that “A lot of people think of it as like a bag of tips and tricks that like you can roll out and then all of a sudden you're culturally relevant educator”.

Summary of Research Question 1

When conceptualizing cultural relevancy in informal science education settings, SCEs centered the audience, but focused on the process of connecting with and engaging audiences and not the outcome, the product of that engagement. Likewise, culture was considered central yet it was “othered,” in the sense that SCEs mostly focused outwardly (on their audiences) rather than inwardly (on themselves). They primarily discussed the culture of their audience or intended visitors and rarely spoke of their own cultural framing. Another key theme emerging from the data was co-development. SCEs conceptualize co-development as a critical part of culturally relevant education, but with a limited or narrow understanding of co-development. They did not speak of co-development from the ground up, but rather by including community stakeholders after the process of development had begun. Sometimes this late inclusion was caused by the constraints of grants or class curriculum.

RQ2: Science Center Educators' Perceptions of the Role of Cultural Relevancy

Although very few research studies on CRE have investigated ISE institutions, CRE has been useful in science classrooms and a case can be made for its potential usefulness in informal science settings (Brown, 2017; Kudumu, 2021). The second research question, "What are SCEs' perceptions of the role of cultural relevancy in science centers," dives deeper into the thoughts of the participants on the purpose of cultural relevancy and its place in informal science education institutions. This question gives insight into the participants' perceived value of cultural relevancy and its possible impact on the learning of science center visitors. SCEs perceived that cultural relevancy played a critical role in informal science education by: (1) pushing practitioners to focus externally on the audience and community and internally on the institution's mission, (2) breaking down barriers in order to increase the public's accessibility to science, and (3) by being a defining factor in ISE institutions, which are fundamentally cultural institutions.

The Role of Cultural Relevancy is to Bring Focus

All but one of the SCEs, 95.5% (n=21) perceived the role of cultural relevancy as helping to focus on their audiences, the communities they come from, and the staff and mission of the institution. Through cultural relevancy, the needs of all stakeholders are considered and power sharing is possible.

The role of cultural relevancy in informal science is to focus on the audience. By bringing the focus of ISE institutions to the audiences they serve, participants described the role of cultural relevancy as having a greater impact on the audience. Dio, for example, thought that with cultural relevancy, learning "becomes more impactful and information is retained longer because it is seen as relevant to them." He used his own life and learning as an example, stating that "I know I am able to retain things longer if I feel it applies to me in my life, and what I do, or anything that can make an extra connection to what I already do." Sara explained that by using culturally relevant educational content, "there's much stronger outcomes. They walk away with a lot more because we've done a really good job connecting it." With these connections made by employing cultural relevance, "it can be really powerful for people to see themselves represented in an exhibit or a program," Anne noted and then illustrated with the following example about an exhibit her institution featured urban heat islands. Anne imagined how empowering it would be for a person of color to see their neighborhood represented in an exhibit. She said she could imagine the person saying, 'Wow, this exhibit is about my neighborhood and people who look like me and what we've experienced, and what we're doing to rectify that experience. That's really cool!'

Anne was not the only participant to recognize that self-representation is empowering and thus the power inherent in cultural relevance. When responding to the question about the role of cultural relevance, Marie was at first hesitant to describe audiences as feeling empowered saying that she didn't "like the word empowered because it gets kind of tricky, like who empowers who." She fought through her reluctance to express her desired role for cultural relevance when she responded:

I hope they feel empowered to do something, whether it's be excited about science, or come to the museum, or do some other museum thing, or just when they hear the word museum think 'Yes, this is me, these are things I should do.' (Marie's interview)

Ir also said that cultural relevance "is something that empowers people to create their own experiences" and that it "encourages scientific/critical thinking." On a deeper level, Ir described cultural relevance as:

> Something that can help people, and children in particular, come to understand their own power. That their power doesn't have to be limited to working within these boundaries that we say exist. I think that if we can teach them that these boxes aren't real and that their experiences are what steers things, then they can seize that power. (Ir's interview)

The participants also described the role of cultural relevancy within the theme of "bringing focus to the audience" as generating mutual respect between the audience and science center's agents (staff, board, and volunteers). For example, C. Harding extolled the engaging role of cultural relevancy in ISE institutions when she responded, "when CRE is used and is the centerpiece of how we're teaching, one of the things that I definitely notice is the kind of engagement level and the investment level that people have." Shawn described how cultural relevancy leads to mutual respect and fun learning. She saw "a difference in the way that they, number one start to respect the space and number two how they just start to respect you and each other. Then they're just having fun learning with you."

While participants' descriptions of audience impact, empowerment, engagement, and mutual respect can all be defined as ways of connecting with the audience, the majority of participants, 73% (n=16), gave responses that specifically fit into the category of connecting with, serving, and prioritizing the audience. These 16 participants described the role of cultural relevancy as helping the audience to feel welcomed, seen and connected. They saw cultural relevance as prioritizing the audience's sense of belonging in the science center specifically and in the world of science in general. Perhaps Donald explained it best when he said:

> For people who may have had those life experiences, it makes them feel seen and included in the science being conveyed. It really gives them a stake in their education, because it makes them invested in their learning and gives them a stake in the process, not just feeling like they're being taught something. (Donald's interview)

The role of cultural relevancy is to make communities central to science centers. Serving the community was seen by many participants as a critical way that cultural relevancy brings focus to ISE institutions. Thirteen participants, 59% (n=13) referred to communities when describing their perceptions of the role of cultural relevancy in science centers. For example, participants like George said:

> Science centers serve the community. I mean, we really exist because well, a lot of us only exist because people want the service that we're providing. So it's mutually beneficial to the institution and to the community we serve if the stuff is pretty relevant to them. Because from our end it's going to meet our educational goals for people's retention and understanding. From the learners, they feel positive about the experience and that the person cares about them. (George's interview)

Bekka also referenced community in her response. She felt that ISE institutions should not only center or focus on community, they should *be* community-based organizations. Her perception is:

> We should be in the community, we should be talking to people, and we should be understanding that the community is a way of knowing and being. I know that there's this

> whole movement of ‘community science’ that is really broad and vague and we're trying to identify it and talk about what it is. We're learning together and so I feel like culturally relevant pedagogy and culturally relevant education within an informal space is acknowledging the fact that we're community-based organization. (Bekka’s interview)

As strongly as Bekka felt about science centers being intrinsically based in the community, she was just as concerned that this concept was lost to many in the informal science field. She worried:

> A lot of science centers have forgotten that they’re community-based. They exist and present as ‘we're science center based’ without recognizing where they're situated. Absolutely! To me that's the biggest loss that happened in the explosion of science centers-- a loss of that community connection. Like libraries do an amazing job of that, right? They know their about their community and they offer what their community needs because they're a hub. Science centers try to be something big to everyone. (Bekka’s interview)

Bekka’s response was the first encounter with a participant that was less than enthusiastic about the surge in popularity that science centers have been enjoying. Her concern that science centers had lost their way was not wholly echoed by any other participant. However, Helen did express concern that science centers should be intentionally culturally relevant and not place the burden of relatability on the audiences’ shoulders. She was clear that science centers “have to be more explicit in making it culturally relevant versus letting the people make it culturally relevant.” C. Harding, on the other hand, envisioned the middle ground, perceiving the role of cultural relevancy as providing the negotiation between science centers and the community. She mentioned:

> The tension that often pops up in science institutions. It is like 'Oh, we have the science and the stuff that we can teach them' and the community's like "Cool, we don't have an interest in that,' or like 'you know, we need this other thing.' So, it's kind of finding and negotiating the space. (C. Harding's interview)

Negotiating the compromise between the science center's desire to remain grounded in scientific concepts and the community's desire to have its needs met, is a challenge that participants felt could be overcome by focusing on the foundational mission of ISE institutions.

The role of cultural relevancy is to bring focus to the science center's mission. By bringing the mission into focus, cultural relevancy provides a mechanism for science centers to reach their full potential and meet their task of interpreting science for diverse audiences and spreading science enthusiasm throughout the general public. In order to achieve these goals, half of the participants, 59% (n=13) perceived cultural relevancy as bolstering science centers' missions by helping to define and support science, keeping in step with educational trends, building the public's science knowledge and trust, and by pointing the public towards the next steps or to science action.

Bekka described cultural relevancy as helping to paint the picture of what the world looks like when science centers achieve their mission of having everyone connected to science as indicated by her following statement:

> It is our lofty beautiful golden rule. It is whatever the 'I have a dream' view is. You know, people of all different backgrounds, walks and classes, experiences and multiple identities, can find a connection in science and understand why we all think it's important. I would want them all to understand and see the importance of science for themselves, for their family, for their community, and for the world. (Bekka's interview)

While Anne also articulated cultural relevancy's role in the mission of making science for everyone, she also warned of the opposite effect. Although she said, "I feel like that's what makes science centers so valuable is their ability to connect all different kinds of people with the joy of learning science and understanding science as a tool for positive change." However, Anne cautioned, "If the only people who get anything out of your institution are from a select privileged sector of your community then you're just missing the mark. It's a huge missed opportunity."

Dio, in his response to the question about the role of cultural relevancy, focused on reducing public fear of science and increasing public science trust. He noted that cultural relevancy could:

> Help reduce some fears or anxieties that we've seen with the COVID-19 pandemic and information about vaccines. It can help increase trust within a community, because, if you are to relate to a community, then they feel that you are trustworthy. They feel that you're not an outsider who was trying to do something malicious, or someone with ill intent. (Dio's interview)

Carmen resonated with the alignment of cultural relevancy to the mission of the science center specifically and of ISE institutions in society. She said that she sees "so much more room and space for this work because our world needs it and our planet needs it, and it just aligns with the missions of our organizations and all science centers." Similarly, Donald perceived cultural relevancy as necessarily complementing science. He did not "think they're mutually exclusive because they impact one another." Donald described the unbreakable bond between cultural relevance and science when he noted that culture helps to define and support science. He said, "I don't think you can have one without the other. You can't really provide scientific data and background without understanding the impact that it may have on culture and vice versa."

Bekka also perceived cultural relevancy as focusing on the mission of humanizing science by representing science as imperfect and ever-changing. She took a strong stance in saying, "that's how we do science. Not just the content of science, but, how we do science and understand the nuance of doing science, as humans. That it's, you know, flawed and challenged and always evolving." Although flawed, Sven saw science as something that could solve the world's problems. He perceived cultural relevancy as creating connections that on some level, provide world solutions. He points to the purpose of science and the next steps of scientific action when he said:

> I just can't see that as anything but a good thing, to connect and understand one another better and to love and respect one another better. I can't see that is doing anything other than helping us solve the many problems that we face as human beings and as inhabitants of a world that we have an ever growing impact on. (Sven's interview)

When leading the public into the next steps--from science-in-theory to science-in-action, it is essential that ISE institutions keep in step with educational trends. Carmen, when describing the role of cultural relevancy in science centers, expressed her concern about the gap between educational research and informal science practice. She explained:

> There's such a disconnect from science centers and so much great work that is happening in the education sphere. I'm talking about culturally relevant education, about multicultural education, and about different pedagogy. There's one I'm thinking of in particular, there's so much work that's happening in that space and it's completely disconnected from science centers and it is in science education. I think that is a tragedy,

> it's a complete missed opportunity. I think there's so much more room and space for this work because our world needs it, and our planet needs it and it aligns with the missions of our organizations. (Carmen's interview)

The role of cultural relevancy is to help science centers share power. While other participants, like Ir mentioned above, talked about using cultural relevancy to empower audiences, 18.2% (n=4), participants discussed the role of cultural relevancy as a means of power-sharing with audiences and the community. Helen spoke of the need for science centers to be places where parents or adult visitors could pass on their knowledge to children. She envisioned "letting it be a space for making, where parents can bring their own experiences and transfer that knowledge and experience to their kids versus us defining that for them." Rose saw the role of cultural relevancy connected to community engagement in ways that share power with the community instead of only producing things for the community. C. Harding also mentioned power sharing as one of the roles of cultural relevancy in science centers. She saw the need for science centers to be responsive to community needs by being flexible with their physical space and by opening up their building for community use. Carmen described cultural relevancy as influencing the power structure of how science centers educate the public and ultimately affecting their mission. She said:

> That older system of educating, where it was this one-way street--I'm giving you all the information, I'm the keeper of everything, you don't know anything, I'm imparting wisdom, we're going away from that. We are teaching each other. You also have something to contribute. By virtue of that, you also have something (and may already be) contributing to the mission. (Carmen's interview)

The role of cultural relevancy is to turn science centers' focus internally. Although several participants spoke of the need for self-reflection during the course of the interview, only three SCEs, 13.6% (n=3) mentioned the focus of self-work as a primary role of cultural relevancy. By focusing science centers on the self-work necessary to effectively reach the public, cultural relevancy "requires us to do our own work and requires us to not be allies, but accomplices," explained Rose. She sees self-reflection, a result of cultural relevancy, as a matter of sincerity that will lead to true outcomes with audiences. As Rose described it:

> When we're using cultural relevancy, if we're sincere in our community engagement and working with people and not just making things for them, then, I see it, impacting them as they are able to see themselves. They're able to make a connection with this thing on a deeper level that gives them a sense of self and a sense of identity. (Rose's interview)

Bekka comments echoe Rose's perception of how cultural relevance begins with personal interactions. Bekka also added:

> A lot of our work really begins personally, right? I'm even thinking about this work on diversity and equity. Just from a risk perspective, so much of it begins with personal interactions. Okay, now I'm thinking about COVID, how do you get these people vaccinated? Well the number one research says their family and friends or people they're going to listen to, talk to them. Well, I also feel like that's part of it right, that's part of what we should be doing as a science center. (Bekka's interview)

Carmen agrees with Bekka and Rose that the role of cultural relevancy is to cause self-reflection. Carmen recognized the challenges of embracing cultural relevancy, saying "You know, DEI, if you're doing it in a responsible way, it really challenges the way you think about the world. That can be really hard and takes a lot of self-reflection and humility."

Similar to Ir, Carmen also called out White supremacy as root of internal conflict that cultural relevancy confronts. She said:

> Unfortunately, because of the way America was created, it's just in our DNA. Whether we know it or not, we're just swimming in it, whether we see it or not, right? I am, I should say, really talking about racism. White supremacy is like in the air. I can't see it but it is there. But when it comes to self-development, it's for everybody to do because everybody has privileges in different ways. (Carmen's interview)

The informal science educators interviewed in this study perceived that cultural relevancy helped to bring the science center's focus externally to the audience and community, as well as internally to the institution's staff and mission. Additionally, respondents discussed how cultural relevancy provided greater opportunities for audiences to access science learning in informal spaces.

The Role of Cultural Relevancy is to Increase Accessibility to Science Centers

Several participants, 27.3% (n=6) spoke of the role of cultural relevancy as increasing accessibility, breaking down barriers, erasing stereotypical images, and making science reachable for everyone. For Sara, "it aims to open doors and windows for people, showing them things that they might not have seen before." For Ir it is about removing images that act as barriers. They said "We have this model of what a scientist looks like. CRE is something that is trying to remove some of those barriers." Other participants emphasized barriers that keep science centers from becoming more welcoming, inclusive spaces. For example, Kristy linked the role of cultural relevancy directly to the dismantling of barriers when she explained:

> Science museums are predicated on the assumption that these really positive experiences in science, make a difference. I'm not sure if we've fully tested that assumption, but let's

just assume that it's correct. If we want to break down structural barriers then having an informal science experience that is relevant and that responds to your needs is really important. (Kristy's interview)

Likewise, Bekka addressed the issue of breaking down barriers to help people who feel that science centers just are not for them. She saw the role of cultural relevancy as encouraging a sense of belonging for minoritized groups. When talking about the role of cultural relevancy she said:

> It's really important, because we know that research data shows that certain ethnic groups, certain class groups, certain identities don't feel that this science center is a space for them. We know that research, so what do we do about it? How do we make people feel like this is a space for them? That is the big question. (Bekka's interview)

One of the ways that cultural relevancy can make science centers more accessible is by using accessible language. Whether it is translating signage and materials into languages used in the community or asking those in the audience to clarify their preferred pronoun, inclusive language leads to positive visitor experiences. Cindy normalized the practice of making museums more approachable for non-traditional groups when she said:

> I think a lot of it is making sure that you're meeting people where they are. I'm thinking about what would make my museum more approachable for a non-traditional groups. Do we have exhibits that are bilingual and, if so, what is the other common language in my area? Spanish is an easy one to recognize, but there's a huge Asian population that uses my museum. What's the dominant language that I should go with? What's the secondary language? (Cindy's interview)

While participants did acknowledge that the changes required by cultural relevancy are challenging, educators like Kristy saw them as necessary for the science center not to do harm. She understood that “it is kind of hard, but it's got to be because if you can't do that, then you are perpetuating that divide that already exists.” To avoid doing harm to the public is an essential tenet of community-focused institutions like science centers. It is not enough to just do good work by presenting science as it currently stands in the world, Kristy argues that ISE institutions must also not contribute to the marginalization of minoritized groups in science.

Cultural Relevancy is a Key Component to ISE Institutions’ Identity

Science center educators perceived cultural relevancy as a key component of ISE institutions. It’s seen as contextually and programmatically integral to the institution’s identity. The role it plays is to build educational structures that model inclusive behaviors such as empathy and curiosity. Rose stressed that cultural relevancy “requires us to have empathy,” and other respondents expressed the idea that cultural relevancy and science centers were “intrinsically bound.” Anne felt strongly about the role cultural relevancy plays in informal science education settings. She said, “I think it's everything…if you are a science center and you are not culturally relevant for the community that you serve, it’s like you have no point to exist…you're just missing the mark.” In their response, Ir expounded upon this concept while at the same time challenging science centers’ notion of cultural relevancy:

> I think that a science center puts out things that it thinks are culturally relevant and in that way kind of defines what may be the popular understanding of what cultural relevancy is and like what being progressive might look like. But, I think that science itself is necessarily democratic and necessarily has to have many, many, many data points and many, many, many different points of views. So, I don't think that you can call yourself a

> science center, let alone a scientist, and reach out to many different people if you are not culturally relevant but you're still trying to turn out your own idea of what that culture looks like. Then you're not getting to either of those objectives. You're not being a science center and you're not being culturally relevant. (Ir's interview)

Anne and Ir were not alone in their perception of cultural relevancy as being integral to what identifies science centers as ISE institutions. About half, 54.5% (n=12) of the participants described the role of cultural relevancy as fundamental to their concept of a science center.

Cultural relevancy is integral to the physical space and programming. Some SCEs, 27.3% (n=6) referred to cultural relevancy as integral to exhibits, programming, or physical space of the science center. For example, Kristy talked about cultural relevancy in relation to the floor plan of the museum. She noted that there is power in the:

> Juxtaposition of the spatial layout of museum exhibitions. The way in which you support large families and the way that you craft the museum to cope with the fact that there are language barriers. I think all of those can tell a much more powerful story about who is welcome and who science is for, then just the spoken words. (Kristy's interview)

C. Harding also stressed that the role of cultural relevancy should be reflected in the physical space of the science center. Like Ir, C. Harding challenged science centers to be authentic in their application of cultural relevancy. She responded:

> If a science organization is really about the community, they need to back that up by being open to the dynamic and the power sharing of what decisions and what programs or exhibits get put into a museum. That is what I would hope the museum could do to be and to have a much more dynamic and responsive [physical] space. (C.Harding's interview)

In addition to their views on the science center's physical space, C. Harding and Kristy expanded upon the value of culturally relevant programming. Anne, Shawn, and Dio joined them in this perception, each mentioning the role cultural relevancy could play, when incorporated as an integral part of programming, in helping science centers become more relevant to the community. Dio articulated his views on this very clearly when he said, "I think the role cultural relevancy should have in an informal science center should be interwoven into the standard programming." Still, Kristy was not satisfied with cultural relevancy only guiding the physical space and programming. She emphasized the importance of cultural relevancy guiding the figurative spaces in between, on one end being allowed to come to science centers and, on the other end, feeling welcomed. She defended this position by saying:

> Well, I think that a lot of what happens on the museum floor and a lot of the museum learning that happens either during events or when attending a program has very little to do with what is said. I mean, I don't know if you've hung out and watched people go through exhibits, but they don't read anything. One out of 10 reads everything and then everybody else just kind of walks around the space. So, I think a lot of the learning and a lot of the opportunities for culturally responsive pedagogy are not just in the text or in the programming, but in the spaces between the programming and the circumstances around the context of the museum experience. So some of it is as simple as who you see on the floor and you interact with. (Kristy's interview)

The spaces in between, as Kristy refers to it, are filled with people. Be they staff, volunteers, board members, or even other visitors, the people that interact with audiences reflect the culture of the institution.

Cultural relevancy is modeled by the people. A couple of SCEs (n=2) expressed that the role of cultural relevancy is to build educational structures that model inclusive behaviors such as empathy and curiosity. In discussing his and his colleagues' role at the science center, Sven noted:

> We are often modeling curiosity. We are often modeling the behaviors that we want people to engage in. One of the reasons we're a science center is because we believe science is an important way of understanding yourself and the world. So, we model that, we say this is how a scientist would look at the world, this is how a curious and interested person would engage with this moment. When you say that's cultural relevance or culturally relevant educational practice, you're starting to say that culturally relevant education practice is important, something worth knowing, and something worth engaging with for yourself. Because the entire process of our educational philosophy is saying that what we're doing with you isn't something you have to know, it's something we believe you'll want to know. We won't walk down this path together if you don't want to. (Sven's interview)

Summary of Research Question 2

When asked to describe their perceptions of the role of cultural relevancy in science centers, participants gave responses that were grouped into three major themes—cultural relevancy brings focus both externally and internally, cultural relevancy increases accessibility, and cultural relevancy is a key component of ISE institutions. Externally, cultural relevancy helps science centers focus on audience engagement, impact, and empowerment. By intentionally centering the community's culture, cultural relevancy prioritizes the audience and generates mutual respect between the audience and the science center. Internally, cultural relevancy brings the science center's focus to its mission of building public science knowledge and trust. This inner work is achieved through self-work that requires self-reflection and self-correction. By breaking down cultural, structural, and systematic barriers, the role of cultural relevancy is to increase accessibility to science centers for marginalized groups. Finally, respondents expressed that cultural relevancy is a key component of science centers because it plays an integral role both contextually and programmatically. It is interesting that SCEs did not talk much about equity, inclusiveness, or the diversity of audiences when describing the role of cultural relevancy in informal science education. Participants tended to define the role more like a road map for science centers to operate as opposed to perceiving cultural relevancy as a guiding principle, which is deeper than a road map. While an external display of cultural relevancy was seen as a determining factor for ISE institutions, it was not described as a guiding principle.

RQ3: Science Center Educators' Culturally Relevant Practices

Findings from RQ1 and RQ2 provide a greater understanding of what SCEs know about the relevancy of culture to the public's understanding and engagement of science, as well as what they think about the role cultural relevancy should play in ISE institutions. However, to gauge the appropriateness of utilizing CRE to tackle issues of diversity, equity, and inclusion (DEI) in science centers it is essential to investigate what SCEs do to apply cultural relevancy. The third research question (RQ3) is "What are SCEs' current practices related to applying culturally relevant principles in science centers?" This question is further defined by two related subsequent questions, "What are SCEs' perceptions of ideal practices to improve CRE in science centers?" and "What are SCEs' perceptions of supports for and barriers to applying culturally relevant principles in science centers?" Together these questions guide the examination of the actual application of CRE. They help to answer how SCEs would like to see it applied, and what helps and hinders them from achieving their hopes and dreams for a more inclusive science center.

Utilizing the constant comparative method, several themes were assigned to the current and ideal practices described by the participants. SCEs recounted current culturally relevant practices that were educator-focused, institutional initiatives, societal driven, and sometimes, acted as barriers to DEI. Participants perceived DEI hiring practices, centering CRE, and CRE-related training as ideal practices for science centers to incorporate. When SCEs discussed barriers to DEI at their institutions, they listed barriers that were systemic, personnel-related, community-related, and caused by the perception of White fragility, the defensiveness prompted by perceived racial critique (DiAngelo, 2018). Respondents also described support for DEI in the form of staff support, co-construction, and allocation of time.

Current Culturally Relevant Practices

When talking about their DEI-related responsibilities at their institution, SCEs also described their own familiarity (or sometimes lack of familiarity) with the institution-wide DEI initiatives, as well as the DEI tasks and duties of other positions. They discussed their institution's DEI focus by diversity category (racial, socioeconomic, ethnicity, gender/gender identity, etc.). Most importantly for the purpose of this research, participants detailed the use of CRE practices at their science center. They included information about whether CRE was used, how it was applied when used, and where in the institution CRE was adopted, if anywhere.

Current culturally relevant practices are educator focused. Over half of the SCEs', 54.5% (n=12) current practices related to applying culturally relevant principles in science centers are educator-focused. One of the subcategories in the educator-focused group of current practices can be called “what educators do with audiences.” Participants described the types of practices educators adopt when interacting with audiences, for example, asking questions, avoiding assumptions, and making audiences feel welcomed. Catherine explained how SCE’s avoid “making assumptions that people drive cars, making assumptions that they have parents, they have a dad, and things like that” when engaging audiences. Dio talked about “asking questions or trying to make references from as many popular cultures as you know.” These audience engagement practices were sometimes described as “showmanship.” George, for example, noted that “there’s overlap between culturally relevant education and showmanship.” He clarified the statement with a description of one of the programs he delivers and the modifications he makes based upon audience age, saying when “I realize that my audience is a bunch of really little kids, I’ve got to adapt on the fly.” Frank, on the other hand, expounded upon the use of inclusive language when he referred to culturally relevant, current practices that were educator-focused. Frank noted:

> There are language choices that can be made that are more inclusive like using adults, instead of parents. I’ve tried to correct myself on it, because you know everyone’s family doesn’t look the same. I think being really intentional about your language and how you can start with language. (Frank’s interview)

In addition to discussing the ways in which they engage audiences, participants also spoke of their personal journey with cultural relevancy and core values found in SCEs across the industry. Another subcategory of educator-focused practices revealed by participants could be labeled as “educators starting with themselves.” Helen sought out professional development in response to her desire to apply cultural relevancy to her work at the science center. She is “personally interested in DEI issues as it relates to human resources and ensuring that our employment practices have a DEI focus." Helen mentioned that she attended the "Racial Equity Institute's level one and level two training." She felt that her institution would benefit from her attendance at the training. According to their website, the "training is designed to develop the capacity of participants to better understand racism in its institutional and structural forms" (Racial Equity Institute, 2022).

Another educator-focused culturally relevant practice was the use of internal listening groups. Ir described the process of putting "together a community listening team" at their institution and how they were nominated to participate. Donald also mentioned that his science center "had numerous community listening sessions" after a new CEO was hired. It is curious that when respondents referred to "community listening" events, they were talking about the institution's internal community. None of the participants discussed listening groups or focus groups that involved people from communities outside of the science center's staff, volunteers, or board. Ir clarified:

> The listening sessions were meant for us to eventually listening to our broader community better in [our city]. But, I think it starts with our own house. The idea is that we are trying to get on the same level within our institution, hear the messed up stuff that's already going on inside. Because we can't serve our community if we can't first of all reflect our community in our makeup. Also if we don't provide an equitable work environment for not just like people who have been in the museum legacy for a while. (Ir's interview)

Another interesting note, is that the respondents appreciated participating in the listening groups, however, they expressed uncertainty about the next steps. Ir noted that "we've had listening sessions within our institution, which were really illuminating. I think there's a big question of what now."

Current culturally relevant practices are institutional initiatives. When SCEs described current applications of cultural relevancy, they listed practices infused in their programming and exhibits, indicative of their institution's DEI focus, supported by institutional strategies, and led by partnerships and grants. All of the participants, 100% (n=22) discussed at least one culturally relevant practice that was supported by their institution and could become an institutional initiative if it were not already instituted throughout the science center. When SCEs gave examples of using CRE in designing programs, participants like Frank talked about ensuring the cultural relevancy of camp curriculum by "talk[ing] about how if we are going to highlight a historical figure, for instance, being really thoughtful about who we highlight." He said:

> We work hard to, when we talk about famous historical scientists to try to pick scientists that aren't just all famous White guys. So using historical examples that are more representative of lots of other people that do good science that we don't talk about. I'm just highlighting a diversity of historical figures that kids can see themselves in. (Frank's interview)

Ir tries to center all of the curricula they write "on ideas of diversity and inclusion" although they "hate using the terms all of the time because the terms are so euphemistic." Ir gave an example of "incorporating indigenous ways of knowing into our nature programming. That is something that gets so misconstrued as primitive, like certain groups are primitive. I feel like it's my responsibility to represent that in a way that is accurate."

Similarly, Anne shared how CRE is incorporated into all of the new exhibits at her science center. She noted that they have “been developing an exhibit over the last couple of years that specifically highlighted issues of equity and diversity. Both Kristy and Dio also mentioned that their institutions featured traveling exhibits focused on race. In fact, a majority of the participants identified racial diversity as one of the major institutional DEI foci. Race was the most frequently identified DEI focus. Ten participants listed race as their institution’s primary DEI focus. Of the 12 participants that did not list race as the primary DEI focus, two listed race as their institution’s secondary DEI focus. Thus over half, 12 (54.5%) of the participants listed race as a DEI focus of their institution. Anne mentioned that her institution is working on “leading with race, where all of the science content that we're developing is going to have a connection to social issues that are meaningful for people and race is obviously one of those.”

Table 8

Participants’ Perspectives of their Institutions’ DEI Focus (N=22)

Focus	Primary Focus	Secondary Focus	Tertiary Focus
Race	10	2	0
Everything	4	0	0
Community	3	0	0
Gender	3	2	1
Ethnicity	1	1	0
Age	1	0	0
SES	0	3	3
Sexual orientation	0	1	1
Persons w/ disabilities	0	0	2
Language	0	1	0

In addition to racial diversity, participants listed age, community, gender, and ethnicity as the primary focus of their institutions' DEI efforts (see Table 8 for frequencies of institution's DEI focus). Four respondents stated that their institution is focused on everything or that it did not have a specific focus but tried to address all DEI-related issues. Of the 18 participants that did not say their institution focused on "everything," 10 noted that their institution focused on multiple DEI issues (seven listed 3-DEI foci and three listed 2-DEI foci). While over half of the respondents (64%) did not have a singular DEI institutional focus, there was a noticeable distinction between the way participants that said their institution focused on "everything" and the way participants that listed multiple DEI-related foci discussed their institution's DEI focus.

Three participants named "community" as their institution's DEI focus. When talking about community, these respondents discussed focusing on community engagement, building and maintaining neighborhood networks, and reaching out to historically oppressed communities. It is interesting that none of these three participants listed anything else as a focus. This was the only category where that occurred. It is as if, when the community is the focus, it encompasses everything else, or possibly, it overshadows everything else.

When asked to name their institution's primary DEI focus, three participants listed gender and three additional participants listed gender as either a secondary or tertiary focus. While sexual orientation was not listed as a primary DEI focus, it was mentioned by two participants. When participants talked about gender throughout their interviews (not only when listing their institution's DEI focus) they discussed declaring pronouns on emails, name tags, and during programs. However, Ir, the only participant to self-identify as non-binary, felt that using pronouns to address issues of gender equality was harvesting low-hanging fruit. Ir commented:

> We love talking about gender, and gender in the very binary sense, because that's kind of low hanging fruit. The gender representation stuff and why I got all of the time that I did, and why it's sort of like a pat on the back, is that something that's easier, maybe in some ways, to do. (Ir's interview)

On the other hand, one participant listed age (or generational diversity) as their institution's DEI focus and another participant listed ethnicity. Although both of these DEI-related topics were not discussed at the same frequency as the others mentioned above, the respondents touched upon issues that are common to all science centers but vary depending upon location. The nature of informal spaces requires a multi-generational approach because audiences are almost always made up of children and adults. Even more so than the racial diversity that makes up the US, ethnic diversity is concentrated regionally and requires science centers to take a nuanced approach to cultural relevancy. The participant that listed ethnicity as the primary DEI focus of her institution noted that the location of her science center necessitated a focus on ethnicity over race, gender, or sexual orientation.

In addition to the ways mentioned above that institutional initiatives supported cultural relevancy, participants discussed bilingual exhibits and programs as well as adult programming and life-long learning opportunities. None of the participants listed socioeconomic status (SES), language, disabilities, or sexual orientation as the primary DEI focus of their institution. However, six participants cited SES as their science center's secondary or tertiary focus, one listed language as the secondary focus, two named persons with disabilities as the tertiary focus, and two listed sexual orientation as the secondary or tertiary focus. Almost half of the participants listed a secondary DEI focus (10) and seven of those listed a tertiary focus.

Table 9.

Practices that Support DEI Identified in Participants' Statements (n=109)

Institutional Practices that would Support DEI	Definition of DEI Support	Frequency (n= 109 total)	Percentage
Staff training	Build staff awareness through regularly scheduled DEI workshops and training	34	31%
DEI-focused hiring process	Refocus hiring processes and attrition on DEI skill sets	20	18%
Allocation of time	Prioritizing DEI by allocating time to build DEI skills, change exhibits and programs, and be with community members	18	17%
Partnerships	Partnerships with community organizations and other ISE institutions	12	11%
Community centered	Putting people first and science curriculum second by making the community the guiding compass	10	9%
Co-construction	Co-design, creation, and construction of programs with teachers and families	8	7%
Process-centered	The process being as important as the product	7	6%

Beyond the institution's DEI focus, SCEs also discussed current institutional initiatives related to applying culturally relevant principles that were categorized as institutional strategies or partnerships and grants. For example, when participants discussed DEI efforts that were supported by the institutional strategy they mentioned gathering DEI committees, appointing DEI officers, funding staff training and professional development, modifying hiring practices to be in line with DEI goals, and including DEI statements in everyone's job description (see Table 9 for a list of the institutional strategies supporting DEI efforts. In Table 9 and the following tables *n* represents a subset of total units of data, (N=788) quotes). Helen noted that at her institution "we don't see DEI as one person's job or the job of a committee. We see it as everybody's job. So we've sometimes had people who want to be the DEI person, but no, we all have to be that. We all have to see that as our jobs." Donald talked about his institution's strategies related to "partnering with our local community to not only uplift them, helping them kind of have a voice and a platform within the larger community, but also like learning from them." Sometimes these partnerships were supported by outside grants. SCEs discussed DEI initiatives that were tied to grant deliverables. For example, Bekka noted that "typically a foundation is going to throw some money at you," and C. Harding described a program that "coincided with another NSF grant that I was doing that was focusing on DEI."

It became clear that as participants discussed the best way to support cultural relevancy, their responses harmonized with their perceptions of institutional initiatives. SCE's perceptions of support for culturally relevant principles fell into three main categories: staff support, co-construction, and allocation of time. Staff support benefits CRE by focusing hiring on DEI skill sets and providing professional development for staff to build DEI awareness. Co-construction benefits CRE by centering the community, collaborating with other science centers on grants, co-designing, co-creating, and co-constructing programs with the community, prioritizing process as much as product, and putting people over the science curriculum. Allocation of time is a benefit to CRE by reserving time to be with community members and setting aside time for personnel (staff, board, and volunteers) to build DEI skills.

Some current culturally relevant practices are societally driven. During the time when the interviews were conducted for this dissertation research (fall of 2021) the US public, in fact, most of the world, was still reeling from the effects of a global health pandemic and the repeated witnessing of racially motivated police brutality. It is, therefore, not surprising that almost half of the SCEs, 45.5% (n=10) described current practices related to applying cultural relevancy as being driven by contemporary societal issues. Many institutions, including science centers, across the country posted documents clarifying COVID-19 restrictions, best hygiene practices, and mask mandates. When the COVID response divided along political party lines and scientific concepts as well as scientists came under attack, science centers leapt into action to define, clarify, and defend the sound science. After the video of George Floyd's murder, at the hands of police officers, was posted online for the world to see, demonstrations, political rallies, and social unrest ensued. Cultural institutions responded with a flurry of statements pledging their support to Black, Indigenous, and people of color (BIPOC) communities. SCEs discussed some of the labors by their institutions to change mission statements, update job descriptions, form support networks, and other efforts to address racial inequities in society by transforming into more inclusive spaces (see Table 10 for a list of societal-driven changes in science centers).

Table 10

Societal Issues Identified in Participants' Statements (n=25)

Societal Driven Changes	Definition of Societal Issue	Frequency (number of quotes of 25 total)	Percentage
COVID-19	Pandemic related restrictions and changes	14	56%
Police racism	Police murder of George Floyd, Breonna Taylor, and others sparked social unrest and racial reckoning	7	28%
Science & society	Science content connected to social issues like science denialism over climate change and pandemic restrictions	4	16%

Ideal Culturally Relevant Practices

SCEs perceptions of ideal practices to improve culturally relevant education in science centers fall into three categories: DEI hiring practices, centering CRE, and CRE-related training.

Incorporating DEI-related hiring techniques improves CRE. SCEs, 22.7% (n=5) cited DEI-related hiring techniques, such as hiring for skills over degrees, as ideal practices to improve CRE in science centers. Participants suggested hiring racially and ethnically diverse staff with real-world experience. C. Harding mentioned that she recently hired “two people that have really incredible backgrounds, but don’t have informal science education experience and don’t necessarily have education degrees, but they have other wonderful skill sets.” Ir, who identifies as White, said that “we should be hiring people who have real-world experience, but they don’t have to all be bright face White people who are ignorant of other people’s ways, like me.” Not every participant described DEI-related hiring practices as embracing racial diversity or educational equity. Frank, on the other hand, stressed the importance of avoiding bias against quiet people, especially quiet children, when hiring. He described his institution’s hiring process and how he reminds candidates to “make sure you don't have this bias of everyone should be bubbly and excited. It's okay for kids to be quiet. I was a quiet, but very engaged child.” Frank’s comments stretched DEI-related hiring techniques beyond racial, gender, linguistic, and generational diversity and equity toward inclusion based on personality traits. Although Frank’s response might seem out of step with the other participants, his understanding is in line with CRE because it considers the possibility of personality traits that might be linked to one’s culture. In some cultures, children are expected to be quiet and reserved when in a learning environment. Frank’s deference to quiet children could be considered centering CRE.

Centering CRE is an ideal practice. Centering CRE by focusing on educators' experiences, knowing the audience, and developing and implementing DEI tool sets, is an ideal practice to improve cultural relevancy in science centers. Several SCEs, 22.7% (n=5) described centering CRE as beginning with the educator. Kristy, for example, commented that she begins by asking educators about their experiences offering informal science education programs. She mentioned:

> I would start by asking them their positive experiences and really negative experiences, where they felt like there are gaps. And then, suggest either in a more formal setting, outreach program, or on the floor activity to think about what actually could fill the gap next time. (Kristy's interview)

Rose also agreed that centering CRE begins with the educator. She said:

> I would tell them that if they wanted to be culturally relevant in their teaching and in their programming that they needed to do the work. Whomever the cultural group is, they need to be part of the development of that content. You need to consider that your White supremacist timelines do not work for those folks. That you need to be planning far in advance. Not "I need this done tomorrow." (Rose's interview)

For other participants, like Frank, centering CRE meant providing DEI tools "like a rubric for how to handle DEI infractions or like DEI pain points" to address conflicts. All of the participants discussed getting to know the audience. For example, Anne noted that her "first step would be to reach out to the stakeholders, the learners, the people that you're wanting to engage with and get some more information from them." Bekka, C. Harding, and Ir all suggested reflective practices, like reading, looking at models, and having group discussions before attempting to enact CRE in the science center. C. Harding said that an organization has "to have a culture of reflection, first in a culture of trust." This type of institutional-wide culture can be introduced and fortified during staff training.

CRE-related training is an ideal practice. SCEs, 45.5% (n=10) also named CRE-related training as an ideal practice to improve CRE in science centers. Participants discussed training by shadowing more experienced colleagues, and attending CRE professional development and formal education classes. They discussed what to teach educators during the training, how to scaffold the learning of CRE concepts and practices, and how to use examples to solidify educators' understanding of CRE. One participant stood in opposition to the idea of CRE training as an ideal practice for new informal science educators. Kristy felt that DEI and by association CRE should not be introduced to new educators. Kristy said:

> I think it's too much for a new educator. I think you have to build people's sense first. You have to build their confidence. I guess it doesn't work for a lot of people, it's not intuitive for a lot of the people that I work with. I think it's hard and I keep saying that but, I think it has to be scaffold on to a series of more advanced kind of interpretation work or more curriculum development. (Kristy's interview)

This response was surprising because it was not in keeping with the sentiment of the other SCEs interviewed who felt that CRE and DEI should be incorporated at the beginning of educators' training. During this section of the interview, when participants were asked "If you could explain to someone who is a new science center educator, how to use CRE at the science center, what would you tell them," one would not expect respondents to say they would not tell educators to use CRE. However, Kristy's admission of how hard it is to apply CRE in science centers was reflective of some of the barriers that SCEs listed.

Barriers to Culturally Relevant Practices

SCEs listed barriers to applying culturally relevant principles in science centers that were grouped into four subcategories: systemic barriers, personnel-related barriers, community carriers, and barriers caused by the perception of fragility. Kristy's decision not to instruct new informal science educators on the use of CRE would also fit under the subcategory of perceptions of fragility.

Some current practices act as barriers to applying culturally relevant practices. Unfortunately, quite a few SCEs, 68.1% (n=15) also described current practices that prohibit the enactment of cultural relevancy in science centers. These practices are characterized as theory-to-practice gaps, inadequate or no use of culturally relevant education, and DEI not being supported by institutional strategy. For example, Ir commented on the focus on racism but not intersectionality, Kristy lamented about the DEI statement that had no "teeth," and Donald complained about the long-serving DEI taskforce that lacked the "power or the ability to create change." George compared the "learning opportunities that we have been given like speakers that relate to diversity and equity," to the absence of meaningful "diversity training or institutional bias training." Table 11 details some of the current practices in science centers that inhibit inclusive environments.

Table 11

Barriers to DEI Identified in Participants' Statements (n=213)

Barriers to DEI	Definition of DEI Barriers	Frequency (n=213)	Percentage
Personnel-related issues	The board is out of touch, all White staff can't portray diversity, constant staff changes and hiring practices inhibit DEI, lack of staff diversity, staff inequity, staff lack DEI knowledge and training, staff perpetuate exclusive culture, DEI responsibility siloed, and staff lack authority and accountability.	90	42%
DEI not supported by institutional strategy	DEI not in job description, is personal initiative, hiring for diversity blew up, implementation is department by department, practices are not organized,	41	19%
Systemic issues	DEI practices ambiguous, industry-wide structural issues, the Whiteness of science centers is an industry-wide barrier, shallow changes maintain old structures, lack of DEI framework for ISE institutions, and lack of funding and time capacity for staff development and training.	37	17%
Community alienation	Community feels uncomfortable and unwelcomed, costs are prohibitive, DEI solutions are not universal, community contribution undercompensated and undervalued, and institutional make up does not reflect local community	17	8%
Theory to practice gap	Institution use but term not formally used, doing CRE but not calling it that, a few people use CRE term, didn't use the word CRE but did practice it	13	6%
Perception of White fragility	Conversations about DEI makes people feel bad and the problem is overwhelming and immobilizing.	10	5%
Inadequate or no CRE	Small institutional use (need to do more) or no CRE	5	2%

White fragility is a barrier to implementing CRE. When asked about the challenges to implementing DEI at their institution, almost a quarter of the participants, 36.4% (n=8) described, either within themselves or someone they know, feeling overwhelmed and immobilized by the magnitude and pervasiveness of the problem. Bekka explained “you can still keep moving forward, you can still take action, you can still keep learning, you can still keep pushing but it feels immobilizing just to keep seeing that the ways that our culture is oppressive are just continually being reproduced.” Carmen referenced the self-reflection needed to implement CRE in science centers. She noted:

> Everybody has privileges in different ways. It can be really hard to have that kind of reckoning moment with yourself. Not only are you having that moment with yourself, but also, you have to recognize the impact that it has on others around you. You have to consider the harms that you caused. Doing that in a workplace, let alone a place you feel safe, is even harder. (Carmen’s interview)

Dio also reflected on the perception of White fragility among his coworkers. He noted that “trying to change the cultural norm makes it seem like you are attaching people. People’s jobs or livelihoods might be threatened.” Dio described the types of reactions he experienced when attempting to enact culturally relevant principles in his institution, which he characterized as predominantly White. He said:

> Pushback isn't the right word, but people can get defensive or feel like they're being attacked by implementing these initiatives. It makes it seem like since the standard ways things worked are not equitable, people have been doing things wrong or that they might get fired for something. (Dio’s interview)

Helen and Kristy also expressed concerns about making anyone feel bad by enacting CRE. Helen noted that science centers in “taking a stand” had to realize “that being welcoming to other groups does mean being a little more political.” She said, “Before we tried to be neutral and now we know there’s no neutral” if you want to work with the community.

Community alienation is a barrier to applying cultural relevancy. SCEs, 31.8% (n=7) reported that communities feel alienated from science centers when the visitation cost excludes the local community and the institutional racial and cultural makeup does not reflect the surrounding community. Communities feel uncomfortable and unwelcome. Participants described how frustrating it is when DEI solutions are not applicable across institutions in various regions of the US. They also commented on the demoralizing feeling when community contributions are under-compensated or undervalued. Anne explained that “you can’t just expect people to perform Spanish for you,” when she described the community pushback her institution received when asking local partners to translate exhibits and programs without proper compensation.

In cases where community contributions are valued, sometimes they are interrupted by staff changes. Catherine commented on the negative impact from staffing changes at her institution and at their local community partners. She noted “A lot of the organizations in our community have had staff changeover as well, and so, once we get a lot of communication established that person may no longer be there when we're trying to continue the communication so we have to start over.” Even when the staff at the science center are stable, they often do not come from the community that surrounds the institution. Donald explained that his institution is aware that they are “a predominantly White institution” and that they do not reflect their local community. Anne echoed Donald’s comments when she described her institution’s lack of racial diversity. She noted, “One challenge is that, despite all of our efforts and grand goals we still as a staff are primarily White.” Anne explained, “Part of it is reflective of the demographics of [the northwest] but also there are reasons that [our city] is primarily White and why people of color are not represented here. It's not a benign thing.” SCEs often remarked on the demographic makeup of the majority of science center staff. In instances where the ISE institution staff does not mirror the surrounding community, unilateral decisions were especially alienating to the community. In one egregious example, an SCE described how the science center changed its name without reflecting on the impact that removing the local city’s name would have on the community where the institution has been located for decades.

Personnel-related problems inhibit CRE. The majority of SCEs, 72.7% (n-=16) recounted personnel issues that inhibit the application of culturally relevant principles in science centers. Participants echoed the responses that they gave when discussing institutional initiatives that would be ideal culturally relevant practices. They listed all White boards being out of touch with the community, staff diversity represented only at the entry-level, and hiring practices that perpetuate the issues. Bekka, for example, explained, “People hire people who are like themselves.” Participants also noted that staff had good intentions but lacked knowledge of how to enact CRE as well as training. This lack of training contributed to a diminishing of educators’ confidence in their ability to use culturally relevant principles. Anne expressed this sentiment saying:

> Am I qualified to teach about this? Who else should I bring in to help talk about this because, I don't want to be just a White girl talking about including non-White people’s insights. That feels a little bit like I’m not representing the people that I’m talking about representing. That's weird. (Anne’s interview)

Unfortunately, when new staff was hired, they conformed to the institutional culture and thus nothing significantly changed. Bekka described this issue saying "I could see that in the science center it's like no matter who we brought in, the new flesh didn't change anything because somehow they adapted to that culture that existed." She went on to illustrate her point with a story about monkeys climbing a ladder, but often interrupted her telling to say, "I know I am not telling this story right." During the process of member checking to validate my findings, Bekka responded and provided a link to a website with details about the monkey experiment that demonstrates organizational culture (https://intersol.ca/news/organizational-culture-and-the-5-monkeys-experiment/). The story describes caged monkeys that learned through negative reinforcement (icy water) not to climb a ladder to collect the bananas at the top. When one monkey tried, the others, who are afraid of the icy water, pull him off the ladder. The monkeys continued to avoid the ladder after the spray of icy water stopped and all new monkeys replaced the ones that had experienced the icy water. The story illustrates the pervasiveness of negative organizational culture. SCE recognized that in ISE institutions, this repetition of inhibitive culture and bad practices leads to systemic barriers.

Barriers that inhibit CRE are systemic to science centers. Most of the SCEs', 68.2% (n=15) perceived systemic barriers to applying culturally relevant principles that were either institutional or industry-wide barriers. Participants spoke of the process for reaching institutional DEI goals as being somewhat opaque. They discussed the public's industry-wide perception of science centers as being places for just one group of people–wealthy, White, college-educated, married couples with young children. Some participants challenged the shallow changes adopted by ISE institutions as maintaining the old systems of power. Criticism of the "good old boy power structure." C. Harding expanded upon this concept saying:

I think that a lot of science centers operate in pockets of particular funding streams. They trying to seek out specific donors, or old money. In institutions, there are often only certain perspectives represented in decision making. Because leadership tends to be White well-off people, who might be doing their best, but they're not seeing the whole picture. I don't know how any one of us can see the whole picture. (C. Harding's interview)

Several participants noted that at the heart of the systemic barriers to cultural relevancy lies systemic and persistent racism. Carmen explained her belief, stating:

I think the heart of it is racism, because that's what our institutions and our country was founded on. It was founded on the blood, sweat, and labor of Black and Brown folks. There's no getting around the fact that people benefited from others being oppressed and that's how our system was built. So, when you don't have any reconciliation, when there is no healing that has happened from generations of oppression, that's how you get to where we are right now. It's just hardwired into the way our society has navigated for decades. It took a lot of time to build that and it's going to take a lot of time to break that down. (Carmen's interview)

Systemic racism was also described when SCEs cited language as a systemic barrier. Cindy explained, "And there's your language in your exhibits, is it up to date? Probably not because exhibits change more slowly. But, certainly you can make sure you're not using the phrase Indian in any of your curriculum because it's inaccurate."

Other systemic barriers listed by SCEs included a lack of funding for staff development, a lack of time capacity to learn about CRE and enact changes, and a lack of a DEI framework for

ISE institutions to use. As noted in the sections above, these same barriers could act as supports or institutional initiatives for inclusive practices if adopted by science centers.

Summary of Research Question 3

SCEs, when asked to describe practices related to applying culturally relevant principles in science centers, included both current and ideal practices, as well as barriers and supports. For current practices, participants listed educator-focused practices, institutional initiatives, and societal-driven practices. They also spoke of current practices that pose a threat to redefining ISE institutions as inclusive spaces. Respondents highlighted current practices that acted as a barrier to CRE and were similar to the barriers that they listed when asked about the challenges to enacting cultural relevancy. Barriers that are systemic, personnel-related, community-related, and those that were caused by fragility were all discussed by participants. When asked what they would teach new informal science educators, participants were given the opportunity to envision the ideal culturally relevant practices. These ideal practices included DEI hiring, centering CRE, and CRE-related training. In order to successfully incorporate CRE in science centers, participants listed practices that reinforced staff, supported co-construction with communities, and prioritized DEI by allocating time for training staff, learning CRE concepts, and changing exhibits and programs.

Relationship to CRE Markers

As the four markers are the structure on which CRE is built, they establish a basis to evaluate educational practices that center cultural relevancy on the principles of academic skills and concepts (AS&C), cultural competence (CC), critique discourses of power (CDP), and critical reflection (CR). Using my revised description for each marker (Table 4), I compared SCE's conceptions about cultural relevancy (RQ1) and perceptions of ideal practices (RQ3a) to the four markers of CRE to gauge the level of application of the educational framework in science centers. Table 12 details the outcome of analyzing RQ1 and RQ3a for the representation of the CRE markers.

Table 12

Prevalence of CRE Marker Alignment in Participants' Responses to RQ1 and RQ3a

Alignment with CRE markers	no CRE	partial alignment	full alignment	All 4 markers
Number of ideal practices (n=22) responses	8	6	8	0
Percentage of ideal practices (n=22) responses	36.4%	27.3%	36.4%	0.0%
Number of conceptualization (n=22) responses	6	14	2	0
Percentage of conceptualization (n=22) responses	27.3%	63.6%	9.1%	0.0%
Number of both ideal & conceptualization responses (n=44)	14	20	10	0
Percentage of both ideal & conceptualization responses (n=44)	31.8%	45.5%	22.7%	0.0%

As Table 12 demonstrates, the analysis of the presence of CRE Markers found that none of the participants incorporated all four of Dover's markers in their conceptualization of culturally relevant education, nor in their descriptions of ideal practices to improve CRE in science centers. Many participants, more than one-third, 36.4% (n=8) when listing "ideal practices" and about a quarter, 27.3% (n=6) when defining cultural relevancy, did not include any CRE markers in their descriptions. It is also notable that responses that could be categorized under one or more of the CRE Markers were often times incomplete examples of the marker. Almost half (45.5%) of the responses represented only partial examples of any given CRE Marker. The adapted description for each CRE Marker is in Table 4 and the representative quotations from SCEs' transcripts are explained in the text below:

Academic Skills & Concepts

When analyzing SCEs' transcripts, I searched for responses that reflected connections to the audience's culture, that were inclusive to all, and that referenced academic skills and concepts. For example, Frank, when giving his conceptualization of cultural relevancy said:

> My guess is cultural relevancy would be using ideas that are more in line with people's lived experiences to make educational concepts and topics relatable to things that they've done in their life or things that they have seen. That would be my guess. (Frank's interview)

Frank's response is an example of a conceptualization that fully reflects the meaning of the AS&C Marker. He is concerned with connecting to the audience through their culture to link them to scientific concepts. This fully representative understanding was not present in all of the participants' responses. Responding to the question about what she would tell a new SCE about ideal culturally relevant practices, C. Harding said:

> I would tell them to take on the role of collaborator. When we think of our roles, we're collaborating with the people and the communities that we work with. As you observe some of the other educators teaching, I want you to pay attention to what are they doing to get input from the audience. What sort of information are they gathering? How do they get people to share? Okay. Let's talk about why these things are important and what that

> tells us from neuroscience, so we can start to build that kind of brain based learning idea which is so important. (C. Harding's interview)

In C. Harding's response, when explaining what she would tell a new educator noted that ideally, SCEs would "take on the role of a collaborator," which fits into a constructivist paradigm. She would also explain why it is important to "build that kind of brain-based learning idea". However, she does not specifically mention working with the audience to build a bridge from their culture to academic concepts or skills.

Critique of Discourses of Power

SCEs' responses that reflected the CDP Marker explicitly spoke of power and dismantling power structures within the museum as well as within society as a whole. Kristy, in her response to how she conceptualizes cultural relevancy, acknowledges the imbalance of power in the education system and seeks to accommodate all people. She said:

> The standards of teaching were built around assessing the learning styles or the family dynamics of a very limited range of people. There are cultural differences in the way that people learn and the way that people respond to the education system. There are differences in the way that their culture has taught them about the power structure and the roles of teachers. A lot of traditional education does not respond to these differences. You have to find ways of tailoring not just how you teach, but what you teach. (Kristy's interview)

In tailoring her instructional techniques as well as her educational content to accommodate audiences of different cultures, Kristy revealed a system of inequity—standards only derive from the culture in power. She seeks to resolve this issue by changing the content and manner in which she teaches. Unfortunately, this approach applies a solution that does not explicitly confront the problem and therefore, can only be a temporary resolution. Because Kristy's solution does not demonstrate the full meaning of the CDP Marker, it is an example of a partially aligned response. Sara, on the other hand, in her discussion on ideal culturally relevant practices said:

> An ideal culturally relevant practice is trying to figure out if the people that we're serving are being seen and heard as individuals. How are we increasing equity of access for all of our learners? How are we making sure that we're pushing up against systems that have existed previously? How are we getting our learners excited about science, are they excited about science? If not, we need to reevaluate why not and that might mean because it's not relevant. (Sara's interview)

Sara's response fully represents the CDP Marker because it discusses dismantling oppressive systems to allow for equity for all. She seeks to engage in critical discourse to understand the root of the problems causing inequity and to reevaluate efforts at solutions.

Cultural Competence

SCEs that are culturally competent strive to learn and teach about, as well as, take pride in all cultures, including their own. Marie's response relates to the CC Marker because is about connections. When asked to describe her understanding of cultural relevancy, Marie said, "I would describe culturally relevant education as education that feels like it connects to a person's own world experience, whether it's their race or their lived experiences." Helen's response was also categorized under the CC Marker. She said:

> I think cultural relevancy is the different funds of cultural knowledge and capital that people bring to an experience, ensuring that no matter what that knowledge or that capital

> is that everyone can find a way to engage and again feel welcome and included. (Helen's interview)

Both Helen and Marie define cultural relevancy in a manner that agrees with the inclusive nature of the CC Marker. Similarly, Shawn, in her response to what she would tell new SCEs about how best to apply culturally relevant practices said:

> I would say, be open-minded. Have that wonderful growth mindset and welcome all the people that you encounter equally. When you're engaging with them, ask questions about themselves and bring that in or tie that into the work that you do. (Shawn's interview)

Critical Reflection

Participants' responses that fully embodied the meaning of the CR Marker included reflection by the audience and the SCEs themselves, recognizing that the SCE represents one of the cultures present. Ir, for example, gives a response that describes their critical reflection on their own cultural identity. Ir said:

> As an educator, you're starting by identifying your own bias and your own cultural framing. Then you are creating a classroom or learning environment that works to remove cultural assumptions from the curriculum and tries to meet students or learners where they are. You incorporate their broader worldviews and realities into the curriculum to have those broader real world applications of these students or learner's daily realities inform the direction of the learning. (Ir's interview)

Ir's response illustrates the portion of the CR Marker that encourages the educator to engage in critical self-reflection of their own culture. The CR description reads, "Culturally relevant educators use inclusive curricula and activities to support analysis of all the cultures represented." Considering that the educator represents one of the cultures in the room, Ir's response ties closely with this section of the CR Marker definition. Carmen's response is another example of acknowledging the cultural identity of the educator. Explaining what she would tell a new SCE about ideal culturally relevant practices, Carmen said:

> I would have them start with themselves and recognize their own assumptions and biases because that comes out when you're teaching, whether you know it or not. Giving new science center educators tools that they can practice to keep themselves in check, so that they're not imparting that bias to the audience. (Carmen's interview)

Although both Carmen and Ir gave responses that partially represented the CR Marker, they both failed to discuss engaging in critical reflection of the audiences' cultures. Other SCEs, like Marie for example, reflected on the differences between the racially diverse audience's representation in science compared to the representation of the dominant culture. Marie said:

> Culturally responsive education involves discovery. That discovery might take the form of reaching out to community organizations that match whatever program or content area is in focus. You can research how's this content is used in everyday life and who is associated with this content area. How does this content represent different backgrounds different races different histories? Historically, a lot of scientists come from upper middle class White folks, that's what we see. But, there are also scientist who come from other backgrounds that we don't see. (Marie's interview)

While Marie's response does involve a comparison of representation in science, it does so only in the case of non-dominant cultures versus White culture. It does not include a critical reflection of non-dominant cultures compared to other non-dominant cultures and it does not engage the non-culturally dominant audience in a critical analysis of their own culture. Additionally, her response neglected to encourage the new SCE to take a critical reflection of their own culture. Marie, however, was not the only participant to give responses that did not fully encompass any of the CRE Markers. Partial alignment with one of the CRE Markers was more common than not.

Full, Partial, and Combined Alignment with CRE Markers

The phenomenon of only partially meeting the definition of a given CRE Marker was quite prevalent: 45.5% (n=20) amongst the combined responses to both conceptions of cultural relevancy and ideal culturally relevant practices. Less than a quarter, 22.7% (n=10) of the combined responses (n=44), fully exemplified the meaning of the associated marker. Table 13 breaks down the frequency of partial and fully matched responses to each CRE Marker.

Table 13

Frequency of Partial and Full Responses to RQ1 and RQ3a Categorized by CRE Marker (n=44)

CRE Markers	Partial Number (Frequency)	Full Number (Frequency)	Total Number (Frequency)
AS&C	5 (11.4%)	1 (2.3%)	6 (13.6%)
CR	3 (6.8%)	3 (6.8%)	6 (13.6%)
CC	10 (22.7%)	5 (11.4%)	15 (34.1%)
CDP	2 (4.5%)	1 (2.3%)	3 (6.8%)
No CRE markers			14 (31.8%)

While, Cultural Competence was the most characterized marker and Critique Discourse of Power the least categorized, Academic Skills & Concepts as well as Critical Reflection were similarly represented—each less than half as much as CC, yet twice as much as CDP. Table 13 also exhibits the frequency of each marker found in the SCEs' responses (n=44). While several of the responses, 34.1% (n=15) represented cultural competence, almost all of them, 93.2% (n=41) neglected to mention the obligation to dismantle power structures in the definition of cultural relevancy and the description of ideal culturally relevant practices. Additionally, only a few responses, 13.6% (n=6) included critical reflection or connections to academic skills and concepts, 13.6% (n=6). SCEs struggled to include the critical analysis of their own cultural identity. Possibly, talking about and accepting others' cultures is lower hanging fruit, while linking those cultures to real scholarship, critically confronting your own cultural framework, and disrupting racist systems are so challenging they seem impossible to reach. Table 11 displays the frequency of CRE Markers represented in the analysis of SCEs' responses from RQ1 and RQ3a. Multiple CRE Markers were rarely, 15.9% (n=7) used to categorize one transcribed quote (n=44) of SCEs' descriptions of or visions for ideal practices to promote cultural relevancy. Of these seven responses, six of them included CC. Table 14 displays the combined markers.

Table 14

Frequency of Participants' Responses Categorized by Multiple CRE Marker (n=44)

Multiple CRE Markers	Number of ideal practices & Conceptualization responses	Percentages of responses categorized by CRE marker
CC + AS&C	4	9.1%
CC + CR	2	4.5%
CR + CDP	1	2.3%
3 markers	0	0.0%
All 4 markers	0	0.0%

None of the responses represented three markers and, furthermore, the SCEs did not conceive of cultural relevancy in a manner that reflected all four of the CRE markers.

Summary of Chapter 4

Findings from this basic qualitative research study revealed SCEs' perceptions and practices of cultural relevancy in learning and teaching science in informal environments. Analysis of RQ1 found that SCEs focused on the audience, 86.4% (n=19), described culture as being central, 63.6% (n=14), and considered co-development essential, 54.5% (n=12) when conceptualizing cultural relevancy in informal science education settings. However, it also found that SCEs tended to limit their focus to initial connections as opposed to long-lasting outcomes, to centralize the "other" culture rather than confronting their own cultural identities, and to limit consideration of co-development to constrained community involvement. Research findings from examining RQ2 illuminated SCEs' perceptions of the role of cultural relevancy in science centers. SCEs perceived cultural relevancy as bringing focus both externally and internally, 95.5% (n=21), increasing accessibility, 27.3% (n=6), and as a key component of ISE institutions, 54.5% (n=12). Although SCEs considered a display of cultural relevancy as a key characteristic of science centers, the role described a road map instead of a guiding principle.

Analysis of RQ3 and the associated sub-questions identified current and ideal, supportive practices as well as barriers to applying culturally relevant principles in ISE institutions. SCEs described current practices that were educator-focused, 54.5% (n=12), institutional initiatives, 100% (n=22), and societally driven, 45.5% (n=10). Participants also envisioned ideal supportive practices including DEI hiring, 22.7% (n=5), centering CRE, 22.7% (n=5), and CRE-related training, 45.5% (n=10). Additionally, participants highlighted practices that acted as a barrier to enacting cultural relevancy. These barriers were categorized as current practices, 68.2% (n=15), systemic in nature, 68.2% (n=15), personnel problems, 72.7% (n=16), community-related, 31.8% (n=7), and those that were caused by White fragility, 36.4% (n=8). Finally, interpretation of participants' responses through the lens of the four CRE Markers revealed that fewer than a quarter, 22.7% (n=10) of the forty-four (n=44) responses analyzed, embodied the full meaning of any of the CRE Markers. Only 15.9% (n=7) of SCEs' descriptions of or visions for ideal practices to promote cultural relevancy were described by multiple CRE Markers. None of the responses represented all four of the CRE markers. Cultural Competence (CC) was the most characterized marker, 34.1% (n=15) and Critique Discourse of Power (CDP) was the least represented, 6.8% (n=3).

CHAPTER 5

DISCUSSION AND IMPLICATIONS

This basic qualitative study explored the potential usefulness of applying the Culturally Relevant Education (CRE) framework towards diversity, equity, and inclusion (DEI) efforts at science centers. The purpose of this study was to report on science center educators' (SCEs) understanding of cultural relevancy, to illuminate their vision for enacting culturally relevant principles in science centers, and to model theory-to-practice research in ISE. Analysis of interview data indicates that participating SCEs had some basic understanding of culturally relevant concepts, they have ideas about the role cultural relevancy should play in informal science education, and they all apply some culturally relevant principles, even when they have not heard of the CRE framework. The results of this study offer new insights into the relationship between SCEs, the institutions where they work, and the audiences that they serve. Findings have implications for SCEs and ISE institutions that might employ cultural relevancy to transform science centers into more inclusive environments, as well as educational researchers seeking to bridge the gap between research and practice in informal science education.

The results of this study point to the potential for enacting CRE in science centers and other ISE contexts and the need for more theory-to-practice research on cultural relevancy in ISE. CRE has the potential to address the identity conflict associated with public engagement in science for audiences from non-dominant cultures and to understand links to greater student outcomes (Aronson & Laughter, 2016; Brown, 2017). Currently, the majority of research studies on CRE focus on formal K-12 educational settings, and are primarily on subjects other than STEM (Aronson & Laughter, 2016; Brown et al., 2019; Kudumu, 2021). Furthermore, there is scant, if any, existing literature that utilizes the CRE framework as detailed by Aronson and

Laughter (2016) to explore the application of culturally relevant principles in science centers. In addition to providing more research in the ISE field, these findings offer an opportunity to study the application of formal educational frameworks in ISE settings. Science education researchers need to study CRE in informal settings because it acknowledges the central role of the educators' cultural beliefs when considering the teaching and learning of science by people from non-dominant cultures. CRE's emphasis on the attitudes and practices of the educator has been useful in formal settings (Aronson & Laughter, 2016; Brown, 2017; Brown et al., 2019) because with it we have learned to utilize the classroom as a place to enact social justice and to embrace societal change in the broader educational community. In response to Sleeter's (2012) call for reframing the public debate about education for historically marginalized communities, this study collects information about what cultural relevancy means and looks like in science centers and applies CRE toward collective empowerment. CRE, as an inclusive pedagogy of opposition, is useful for ISE settings because it can illuminate how cultural and political biases affect science content knowledge, beliefs and understanding. Using CRE to confront the ISE status quo supports research and practice that contribute to cultural inclusivity in ISE settings.

Major Findings

Although findings were not intended to be generalizable across the broad field of science centers in the US, together, the shared experiences of these 22 participants provide some insight into the perceptions and practices of SCEs regarding culturally relevant education in ISE institutions. I synthesized the findings from this study to create the following three assertions regarding cultural relevancy in informal science education settings given the knowledge, thoughts, and actions of 22 SCEs from 15 institutions across the US:

1. Cultural relevancy in informal science education is dependent upon a mutually respectful relationship and shared culture developed between the ISE institution, the audience, and the personnel at the institution. Yet, the connection with the audience is often shallow, the relationship with the institution is usually one-sided, and the sharing of culture is habitually hampered by exotification.
2. The role of cultural relevancy is integral to ISE institutions' achieving their mission of engaging the community by increasing accessibility to science. Still, this role functions like a tool kit, or a road map to reach the goal of cultural relevancy, as opposed to the deeper guiding principle of being inclusive.
3. The application of culturally relevant principles includes learning about the audience and co-construct science understanding with them. However, institutional and field-wide systemic issues that alienate the community are barriers to enacting culturally relevant practices in science centers.

These assertions address the three research questions by summarizing how SCEs defined cultural relevancy (RQ1), envisioned the role of cultural relevancy in science centers (RQ2), and applied culturally relevant practices (RQ3). Additionally, the findings outline what SCEs perceive as the barriers that inhibit the enactment of CRE in science centers. I expand upon each of these assertions and accompanying counterarguments in the subsections below.

Cultural Relevancy is About Relationships

Similar to formal science teachers (Villegas, 2007), SCEs' who participated in this study turned to their belief systems to help them rationalize their experiences and provide meaning to their worlds. SCEs' conceptualization of cultural relevancy is influenced by their beliefs about the concept of culture more generally, the culture of science, and their own culture (Howard, 2019). Although science centers struggle to attract diverse audiences (Falk & Dierking 2013; Rennie, 2014), SCEs are still committed to helping ISE learning environments live up to their charge of bringing science to the broader public (Tlili et al., 2006). A majority of SCEs reported that they employed inquiry-based methods and constructivist techniques to build relationships with the audience. Busch et al. (2022) found that awareness of the cultural context of the audience is a component of the informal pedagogical content knowledge of SCEs. It is, therefore, not surprising that SCEs centered their own relationship with the audience when they conceptualized cultural relevancy in informal science education.

By centering the audience, SCEs acknowledged that the cooperation of the community is essential for the science center to achieve cultural relevancy. SCEs agreed with educational researchers that ISE institutions must build lasting relationships with diverse communities to achieve greater inclusion in science (Dawson, 2014b; Feinstein & Meshoulam, 2014; NRC, 2009). SCEs conceptualized co-development as a critical component of cultural relevancy and indispensable for ISE institutions to establish and maintain connections to the community. SCEs understood that when ISE institutions committed to co-constructing programs and exhibits with diverse communities, they supported the application of culturally relevant principles in science centers.

SCEs described leading their institution's commitment to cultural relevancy by initiating internal listening groups, forming staff DEI committees, and pushing for greater staff diversity to help change the culture of the science centers where they work. SCEs understood that without the ability to appeal to diverse cultures, ISE institutions will cease to be relevant to the growingly diverse public and, therefore, will fail to achieve their mission (Rennie, 2014. p. 124). Similar to how Vygotsky and Collins place the role of culture central to the development of consciousness

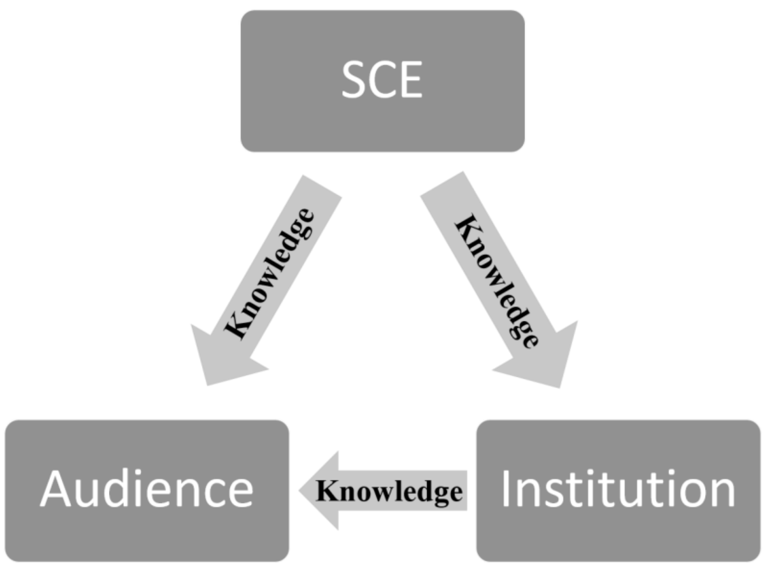
(Collins, 1989; Vygotsky, 1978) SCEs conceptualized culture as central to establishing the science center as a culturally relevant social institution. They considered themselves the drivers of cultural relevancy within their institutions through their personal connections to the culture of the audience and their continual push to get the science center to recognize and honor the culture of the communities where they are located.

While SCEs understand that cultural relevancy is dependent upon mutually respectful relationships and the co-development of a shared culture, they described one-way relationships that “othered” non-dominant cultures. For example, SCEs sought to gather and use cultural artifacts from the audience to aid in their delivery of scientific content. This is a “push” or one-way communication of knowledge from the SCE to the learner. Similar to science educators in formal settings (Rudolph, 2019), SCEs do not expect to be fundamentally changed, nor do they imagine that their own understanding of science will change because of the cultural contributions of the audience. The audience’s culture might enhance scientific interpretation; however, in science centers, SCEs present scientific knowledge to the learner and not the other way around. Likewise, the relationship between the ISE institution and the audience is another example of one-way communication.

SCEs acknowledge that the role of the science center is to facilitate public understanding of science (NRC, 2009). Yet, ISE institutions rarely have mechanisms to participate in a reciprocal relationship with the audience (Equity in the Center, 2020; Garibay & Olson, 2020), whereby the institution also learns from and evolves because of its relationship with the audience. Instead of a science conversation, ISE institutions engage in science-talk or one-way communication where scientific knowledge flows from the institution or the SCE to the audience and not the other way around. Furthermore, SCEs find themselves leading the charge for DEI and dragging their institutions along because of their individual commitment to cultural relevancy. SCEs' want more than the current one-way relationship, where they give relentlessly to the institution in the service of the greater good but receive little knowledge and low pay in return. They vocalize their desire through calls for DEI-related professional development, DEI mission statements with "teeth," and greater accountability towards DEI-derived goals across the institution (Ennes et al., 2020). See Figure 5 for an illustration of the one-way relationship representing the flow of knowledge in general, and in specific scientific knowledge, between SCEs, ISE institutions, and the audience they serve.

Figure 5

One-way Relationship Between SCEs, ISE Institutions, and Audiences



Cultural Relevancy is the Point

SCEs recognize the important societal role ISE institutions play in the public understanding and engagement in science (NRC, 2009). However, they are also aware that in the US, where the majority of STEM-related fields are populated by people of European ancestry, and thus represent the dominant culture, it may be challenging for non-dominant communities to claim their place in science (Carlone and Johnson, 2012; Gay, 2018; Howard, 2019). Participants acknowledged that accessibility issues are systemic to science, as a whole and to ISE institutions specifically, and are primarily responsible for science centers failing to popularize science. This view is also reflected in the assertions of ISE researchers like Feinstein and Meshoulam (2014), Dawson (2019), and Ash (2022). SCEs envision science centers breaking down structural barriers to science and making involvement with science attainable for non-traditional museum visitors by prioritizing cultural relevancy. According to SCEs, the role of cultural relevancy in informal science is to provide ISE institutions with a mechanism to meet their mission of making science accessible to the public.

SCEs are aware that engaging in informal science learning can positively influence audiences' involvement with science and their understanding of science-related social issues (Dorsen et al., 2006; Stocklmayer et al., 2010). SCEs also understand that communities that are inhibited from participating in science will be further marginalized (Dawson, 2014b). While the cultural framework that guides science is euro-centric and often fails to address issues of equity and access (Dawson, 2014a), SCEs place stock in the possibility of ISE institutions achieving their promise to bridge the gap between scientific discovery and the general public (Rennie, 2014). According to SCEs, cultural relevancy brings greater focus to the audience and to the self-work necessary to effectively reach the general public. By sharing power with the audience, SCEs intentionally center the community, prioritize audience engagement and impact, and build public science knowledge and trust. SCEs perceive the role of cultural relevancy as the means to focus externally on the audience and community as well as internally on the staff and the mission of the science center.

SCEs understand that the internal work necessary to transform science centers into environments that attract and welcome more culturally diverse audiences begins with personal interaction and self-reflection (Garibay & Olson, 2020). Through self-awareness, science centers must concede the fact that they are cultural institutions and as such are not neutral (Equity in the Center, 2020). Although the science is often presented as apolitical and acultural, it represents the dominant population's politics and culture (Howard, 2019; Riley et al., 2014; Rudolph, 2019). SCEs feel that in order for science centers to achieve their mission, they must take a stand by encouraging, teaching, and demonstrating empathy. SCEs realize that cultural relevancy plays an integral role in science centers, both contextually and programmatically. They see the role of cultural relevancy as building educational structures that model inclusive behaviors such as empathy and curiosity.

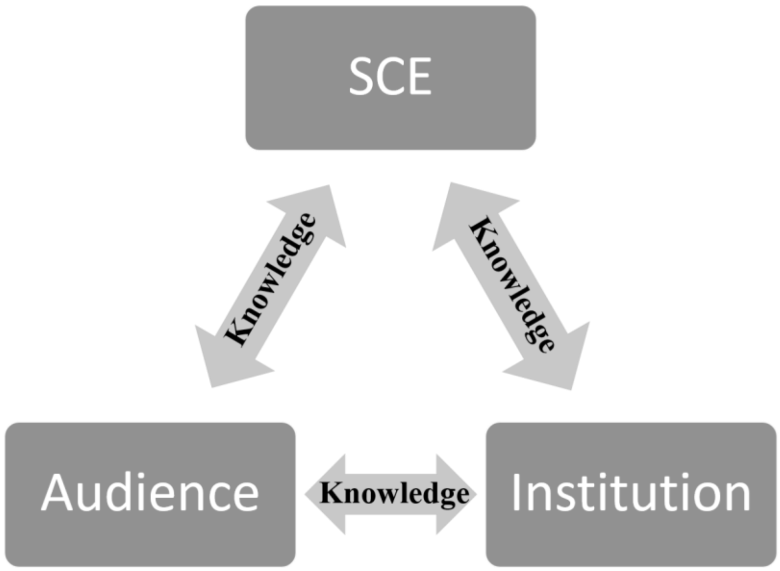
Although SCEs understand that as cultural institutions it is imperative that science centers are culturally relevant, they struggle with how to move beyond the role of ally into the position of an accomplice. While allies make personal changes, accomplices work to dismantle oppressive systems (Lamont, 2022). As Tlili et al. (2006) noted, it is not enough for science centers to continue playing to the same middle to upper-class, White audience. SCEs and ISE institutions must disrupt the status quo to demonstrate that science, at its best, can represent a multitude of cultures (Tlili et al., 2006). Critical researchers explore the relationship between learning and culture (Freire, 1970/2018; Giroux, 2020) and SCEs claim that cultural relevancy is a key component of ISE institutions, and that it is intrinsically bound to what makes science centers societally important.

Despite SCEs' desire for more systematic CRE, they also search for ways to simplify its adoption. Although they recognize the role of cultural relevancy as integral to increasing accessibility to science, too often, cultural relevancy is seen as a road map to reach a goal of greater diversity, rather than a deeper understanding of being inclusive. Cultural relevancy is not one size fits all and, therefore, it cannot fit neatly into a DEI tool kit, pulled out of the closet when ISE institutions want to increase the cultural diversity of their audiences. Cultural relevancy requires that SCEs and ISE institutions consider the role the current conditions of the audience as well as the historical relationship between the audience and the Euro-centric culture plays in the learning and engagement of science (Collins, 2000). When SCEs and ISE institutions are able to make culture central to knowledge validation (Collins, 2000), they will begin to move beyond one-way-knowledge-flow relationships to true co-development.

Falk and Dierking (2019) recommend placing the audience at the center of science learning, "as an active co-constructor, not merely a passive recipient," (p. 7). Efforts in sustainable science and global environmental governance also emphasize knowledge co-production as a means of initiating structural change within community-to-institution relationships (Maclean et al., 2022). Although it is called by many names—co-production, co-construction, or co-development—belief in this process accepts that the meaningful contributions of the audience, SCEs, and science centers, as holders of institutional knowledge, come from lived experience with the power to transfer knowledge to practice. Figure 6 illustrates the reciprocal flow of knowledge (scientific and otherwise) between SCEs, ISE institutions, and audiences.

Figure 6

Two-way Relationship Between SCEs, ISE Institutions, and Audiences



SCEs Enact Cultural Relevancy

SCEs practice cultural relevancy when they query audiences, incorporate cultural perspectives from the audience into their programs, and use cultural contributions to help the audience build greater scientific understanding. This constructivist approach to presenting science is prevalent in science centers across the US (Rennie, 2014) and is easily recognized, named, and adopted by SCEs. Educational researchers, such as Falk and Storksdieck (2005), encourage the use of sociocultural context when ISE institutions engage diverse audiences. When applying cultural relevancy, SCEs employ educator-focused practices in that they detail the actions of the educator, for example, what the educator is doing with the audience --asking questions, avoiding assumptions, and welcoming the audience. SCEs also practice culturally relevant principles when they participate in DEI committees and internal listing groups.

Likewise, this internal use of cultural relevancy is educator-focused in that it concentrates on in-house issues and seeks to influence the culture of the ISE institution.

SCEs' culturally relevant practices are sometimes institutional initiatives in that the institution promotes them even if the institution does not always initiate them. Through institutional initiatives, SCEs practice cultural relevancy in program and exhibit development. They seek to incorporate diverse cultural views by focusing on life-long learning, considering accessibility issues, keeping in mind LGBTQ issues, and highlighting DEI when discussing the program and exhibit design. Comparable to assertions made by educational researchers on the nature of school culture, SCEs understand that institutional culture exists and is reflective of the dominant culture (Carlone & Johnson, 2012; Howard, 2019). In science centers that have a DEI focus supported by internal strategies, SCEs practice cultural relevancy by helping their institution enter into partnerships with community organizations and other cultural institutions. SCEs are clear about the ideal practices that they would like to see their institution engage in, for example, DEI hiring techniques and training. They apply for grants, seek out traveling exhibits, and advocate for the adoption of industry best practices to enhance DEI efforts at their science center.

Similar to the best practices of science teachers in the application of justice-centered science pedagogy, SCEs' best practices will necessarily consider and respond to the current societal contexts (Morales-Doyle, 2017). SCEs' culturally relevant practices are societally driven in that the institution and SCEs react to contemporary societal issues like climate change, racially motivated police brutality, science denialism, and the impacts of the COVID-19 pandemic. By considering these current issues when interpreting science, SCEs contextualize the science content within the audience's frame of reference (Brown et al., 2020). SCEs recognize that as the validity of science concepts from human-induced climate change to the contagious nature of pandemic-level viral spread are under political attack (Oreskes, 2021; Pazzanese, 2020), science centers cannot afford to appear neutral. By engaging in culturally relevant practices, SCEs address contemporary issues directly and place the audience at the center of science engagement (Weiland, 2015; Zimmerman et al., 2009). For example, SCEs enacted culturally relevant practices ignited by the racial reckoning resulting from the murder of George Floyd. The racially motivated, publicly viewed and viral streaming murder of a Black man at the hands of police sparked internal conversations at science centers around the world. SCEs responded to the public outcry by urging their institutions to make public statements condemning the murder and supporting the Black Lives Matter movement.

Although SCEs enact cultural relevancy by learning about their audience and using that information to help the audience co-construct science, they do not focus on their own cultural and science capital, their unique "science –related forms of social and cultural capital," (Jones et al., 2020, p. 1549). Participants did not reflect on the cultural, social, and academic features of their lives that fueled their love for science. SCEs refrain from sharing their own cultural perspective and therefore neglect to make authentic connections with the audience. This contributes to the lopsidedness of the relationship between the SCE and the audience and gives credence to the notion of the audience's culture as the "other." Adult learners, including SCEs, rely on guidance from their personal and cultural context, as well as their perception of themselves (Falk & Storksdieck, 2005). Some SCEs do not recognize that their own culture affects the way that they understand and interpret science. Their cultural influence is invisible to them because it blends in with the culture of science, which coincides with the dominant culture of society (Carlone & Johnson, 2012). The diverse audience comes from a culture that is "other" than the dominant culture of science and the majority of SCEs. Through the process of "othering" these diverse cultures are exoticized as the dominant culture is viewed as neutral or non-existent (Ash, 2022; Dawson, 2019). This exoticism complicates the relationship between the non-dominant community and the science center because it limits the contributions to tokenism and inhibits authentic connections.

Furthermore, some current practices by SCEs and ISE institutions act as barriers to applying cultural relevancy. These practices exacerbate the theory-to-practice gap where SCEs have heard of CRE and may partially implement culturally relevant principles, but do not fully understand the educational theory, or in some cases, CRE is not enacted at all. Barrier practices represent misalignment between stated goals and actual institutional procedures. For example, there is misalignment when science centers seek to attract diverse audiences, however, DEI is not actively supported by institutional strategy, it is not in the job description, it is only undertaken when it is a personal initiative of a staff member, and no time is allocated to support the application of cultural relevancy.

Personnel-related issues also create barriers that inhibit the application of culturally relevant principles in science centers. Research on SCEs in the US reveals a population who is predominantly middle to high economic status, White females between 20-30 years of age (Ennes et al., 2020; Ruffo, 2013). While SCEs are aware that all White senior level staff and museum boards preserve the exclusionary nature of ISE institutions, they are reluctant to change this demographic because it might mean removing some well established experts in the field (Equity in the Center, 2020). This fear of offending someone, or having to kick someone off the team, perpetuates the notion of White Fragility, the defensive posturing triggered by any amount of racial stress (DiAngelo, 2018). DiAngelo (2018) describes the defensive moves associated with White Fragility as “the outward display of emotions such as anger, fear, and guilt and behaviors such as argumentation, silence, and leaving the stress-inducing situation,” (p.103). The perception of White Fragility is a barrier to applying culturally relevant principles in science centers because it seeks to “reinstate White racial equilibrium,” (DiAngelo, 2018, p. 103). Combined, these institutional and field-wide systemic issues alienate communities and act as barriers to enacting culturally relevant practices in science centers.

Implications

The findings from this study and resulting major assertions have implications for research and practice in the field of science education in informal settings.

Implications for Future Research

SCEs and ISE institutions are still following the direction set by foundational educational theories such as constructivism, an educational theory founded decades ago. According to Ash (2022), “Since the late 1960s, many museums, such as the Exploratorium and other science centers, have come to rely on constructivism and experiential ‘learning by doing’, often framed as inquiry,” (p. 228). Falk and Dierking (2019) recognize that public science education requires a comprehensive, equitable approach that centers the learner and that this approach is currently missing from ISE. Dawson (2019) acknowledges the limited empirical and theoretical research on equity in science learning and the negative impact on practice in ISE institutions. Science centers lag behind educational trends and concepts developed in academic institutions that are increasingly focusing on social learning, learner collaborations, and the connection between learning and equity (Ash, 2022; Dawson, 2014a). For example, while constructivism inquires about the concrete experiences of the audience (Vygotsky, 1978), it does not account for changes to the system from the new knowledge provided by the audience. In other words, while science centers agree that audiences construct their own knowledge, however, without valuing the unique cultural perspectives, these institutions will fail to make authentic connections (Dawson, 2014a). Critical pedagogies that center culture require SCEs to forge genuine relationships with audiences. On the other hand, educational theories and pedagogies developed by educational researchers overwhelmingly focused on formal education and overlooked the opportunity to inform learning and teaching in non-formal spaces like science centers (Ash, 2022; Dawson, 2019). This resulted in a lack of strong research-to-practice frameworks developed intentionally for ISE (Dancstep & Sindorf, 2018).

Fortunately, research does provide some suggestions to improve the use of CRE in science learning. For example, researchers like Bottoms et al. (2015) and Brown et al. (2019) combined theoretical concepts with practical applications to develop tools for studying science teachers' cultural responsiveness. Sleeter (2012) made the case for demonstrating student outcomes in formal education through more evidence-based research on applying CRE. Dover (2013), considering the scope of critical and cultural pedagogies, their relation to one another, and the resulting gaps, coined the four markers which are the tenets of CRE. Aronson and Laughter (2016) further developed the framework by adding descriptive statements for each of the four CRE markers. In response to Sleeter, Aronson and Laughter (2016) provided a review of studies that demonstrated increased student motivation, confidence, content interest, and ability to engage associated with the application of CRE.

Similarly, ISE research can benefit from modifications of CRE prescribed in this study (see Table 4 for the descriptions of CRE Markers adapted for ISE institutions). For example, ISE researchers can follow the lead of formal educationists by designing empirical studies that investigate the impact of CRE on audiences' academic skills and concepts. Demonstrated connections between CRE and audience outcomes can further justify the need for science centers, as well as provide the rationale for utilizing CRE in ISE settings. Additionally, through exploration of the modified CRE Markers, ISE researchers can define predictors of academic gains, critical cultural reflection, and cultural engagement beyond the constraints of formal educational measures. Constraints such as standardized testing and policy-driven metrics, for the most part, do not plague science centers. Unconfined by these restrictions, ISE researchers can avoid the conflict inherent in assessments that prevent the unmasking and dismantling of oppressive systems. CRE-defined metrics can be useful to practitioners.

Implications for Practice

CRE adapted to an ISE framing has implications for daily practice in science centers. In addition to CRE-based metrics (potentially developed by ISE researchers), the four CRE markers act as signposts to guide SCEs along the continuum of cultural relevancy. For example, SCEs familiar with constructivism, one of the primary educational theories enacted in most science centers (Ash, 2022; Dawson, 2014a) SCEs can engage the first CRE Marker by connecting their own cultural references to academic skills and concepts, thus modeling for the audience ways to construct bridges while at the same time encouraging the inclusion of all cultures. Addressing the second and third CRE Markers by demonstrating critical reflection of their own culture, SCEs create safe spaces for audiences to learn about and value their own and others' cultures and critically analyze the cultural ties to science. SCEs actively pursue social justice by unmasking systemic oppression in their efforts to center culture while societal issues drive their practices and White Fragility attempts to stall their progress (the fourth CRE Marker).

Although educational researchers such as Gorski and Swalwell (2015) argue that cultural-examining pedagogies, like culturally responsive teaching, culturally responsive pedagogy, and culturally sustaining pedagogy, can encourage tokenism and surface approaches to systemically deep problems by centering culture instead of equity, I suggest that SCEs enacting CRE can avoid this pitfall. By adhering to the descriptive statements that clearly define the vision for a culturally relevant environment, SCEs are reminded to continually work for social justice (Aronson & Laughter, 2016) and inclusivity in informal science learning (Ash, 2022; Dawson, 2019).

Areas for Future Research

This research offers a launching point for experts in the field of ISE to build upon these findings to explore further the results of adapting the CRE framework for ISE environments. Future investigations should include empirical testing of the modified framework, soliciting and incorporating feedback from ISE practitioners and researchers, and triangulating interview data with observations and the analysis of artifacts from the field. Additional research could also compare theoretical frameworks that center culture verses those that center equity. Finally, future research could explore how other formal educational theories could be adapted to address the lack of robust research to practice frameworks for ISE.

Conclusion

While there are relatively few studies designed to explore issues of DEI in ISE contexts, and none specifically investigating the perceptions and practices of SCEs regarding CRE, there are a couple of studies from which this work builds. The CCLI National Landscape Study reports on the state of DEAI practices in museums of all kinds (Garibay & Olson, 2020). Grated this study paints a comprehensive picture of issues in museums in the US, it is inclusive of institutions across subject matter, including for example art, history, and science museums amongst others. The data and findings are reported in aggregate and it is not possible to tease out the results related specifically to science centers. The other study is “Awake to Woke to Work: Building a Race Equity Culture” developed by Equity in the Center (2020), which defines a Race Equity Cycle that all cultural institutions go through. Again, the aggregated data for this study does not directly correlate to science museums. Although helpful for understanding the nuances of the non-profit world, neither of these studies is specific to learning and teaching science. While CRE was not designed specifically to inform practices in STEM subjects, it has been adapted and utilized in several studies of formal math, science, and engineering classrooms. The findings presented here expand upon the knowledge gained in the CCLI and Equity in the Center studies as well as the other studies of CRE used in formal STEM education. The modification and adoption of CRE benefit the field of ISE in both research and practice because it provides an example of how to bridge the gap from educational theory to practice.

As science centers battle to remain relevant in a market with rapidly expanding edutainment opportunities, addressing DEI problems and exclusionary perceptions is critical to their survival. During this time when science is being attacked in the US and science denialism is split sharply along party lines, science centers must step out from behind the false cover of neutrality and confront the culture and politics of science, which are cut from the same cloth as the dominant population. The possibility of using CRE, and other frameworks gleaned from formal education, to tackle issues of DEI in ISE environments, looks promising.

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APPENDICES

Appendix A

Science Centers from the CCLI Study (Garibay & Olson, 2020)

Adventure Science Center
Air Zoo
Ann Arbor Hands-On Museum
Arizona Science Center
Bay Area Discovery Museum
Bell Museum
Bramble Park Zoo
Brevard Zoo
Buffalo Society of Natural Sciences
Cape Fear Museum of History & Science
Carnegie Museum of Natural History
Carter County Museum
Cascades Raptor Center
Centennial Museum and Gardens
Center for Aquatic Sciences
Charles Allis Villa Terrace Museums Inc.
Como Park Zoo and Conservatory
Connecticut Science Center
COSI
Creative Discovery Museum
Daniel Stowe Botanical Garden
Denver Museum of Nature & Science
Desert Botanical Garden
Detroit Zoological Society
Discovery Center at Murfree Spring
Discovery Place
Exploration Place
Exploratorium
Fiske Planetarium
Frost Science
Green Bay Botanical Garden
Henry Plant Museum
Houston Museum of Natural Science
Impression 5 Science Center
International Museum of Art & Science
Kentucky Science Center
Lawrence Hall of Science
Leach Botanical Garden
Lincoln Park Zoo
Lynn Meadows Discovery Center
Monterey Bay Aquarium
Morven Museum & Garden
Museum of Discovery and Science
Museum of Life and Science
Museum of Science, Boston
National Eagle Center
National Mississippi River Museum/Aq.
Natural History Museum of Utah
New England Aquarium
New York Hall of Science
North Carolina Museum of Natural Sciences
Ohio Valley Museum of Discovery
Orlando Science Center
Paper Discovery Center
Queens Botanical Garden
Robbins Hunter Museum
Roberson Museum and Science Center
Rochester Museum and Science Center
Roseville Utility Exploration Center
Saint Louis Science Center
San Diego Museum of Man
San Diego Natural History Museum
Santa Barbara Museum of Nat. Hist. & Sea
Santa Cruz Museum of Natural History
Science Center of Iowa
Science Central
Science Museum of Minnesota
Science Museum of Virginia
Shenandoah Valley Discovery Museum
Space Center Houston
Spark! Imagination and Science Center
spectrUM Discovery Area
St. George Dinosaur Discovery Site
The Academy of Nat. Sci. of Drexel Univ.
The Discovery Center
The Discovery Museum
The Field Museum of Natural History
The Rubenstein Museum of Sci. & Tech.
The Natural History Museum of LA County
The Tech Interactive
The Wild Center
Thunder Bay National Marine Sanctuary
Tower Hill Botanic Garden
United States Botanic Garden

Appendix B

Screening Questions and Probes

The screening questions are listed numerically and the follow up probes are listed with letters.

1. How would you describe your race and ethnicity?
2. How would you describe your gender?
3. What level of experience do you have with informal science education?
    a. Would you say you are extremely experienced, moderately experiences, not very experienced?
    b. How many years have you worked in informal science education?
4. What is your position at your organization?
5. What is your organization's type?
    a. Who are the intended audiences?
6. What is the size of your organization?
    a. How many staff, volunteers, board members?
    b. Is your budget large, medium, or small compared to other similar institutions?
7. In your opinion, how successful is your institution at diversity, equity, and inclusion?
8. What diversity, equity, and inclusion practices have you employed at your institution?
    a. What role did you play in these practices?
    b. Who initiated these practices?

Appendix C

Interview Protocol

1. The researcher will email a copy of the Consent Form and Research Information Summary to the participants.
2. The researcher will schedule video interviews via the Zoom platform and send the evite to potential participants. Individuals agreeing to become participants will signal their consent to participate in the study by accepting the call evite.
3. The interview will be recorded by the Zoom platform, which generates a warning to the participant that the call is being recorded and provides the opportunity to decline participation.
4. The researcher will collect pseudonyms instead of personally identifying information (such as a name) from each participant.
5. The researcher will conduct semi-structured interviews of the participants using the questions and probes listed below.
6. The researcher will review the informed consent with the participant, inform the participant that the purpose of the interview is to access their thinking about cultural relevancy in informal science education, and assure the participant that all identifying information will be removed before the information is analyzed.
7. The researcher will encourage the participant to speak freely and give as much or as little information as they feel comfortable.
8. The researcher will explain that there might be some follow up questions to clarify their responses and that the participant can discontinue the interview at any time.
9. The researcher will answer any questions the participants have before the interview begins.

Interview Questions and Probes

Demographic

1. What pseudonym would you like to use instead of your name for this study?
2. Tell me about your work experience as a science center educator.
    a. How many years have you been a science center educator?
    b. Where have you worked?
    c. In what capacity did you work for each science center?
    d. How were you trained to be a science center educator?

Institutional Culture

3. How would you describe the culture of the science center where you currently work?
    a. How do you define culture?
    b. Is the culture of a person or group of people defined differently than the culture of an institution?
    c. How would you describe your own culture (background, family, religion, food, clothes, music, mood)?
    d. How would you describe the culture of the science center where you work to s professional colleague that you just met versus a friend who also works in your institution?

Institutional Diversity, Equity, and Inclusion

4. Tell me about DEI related responsibilities at the science center where you currently work.
    a. What are your DEI related responsibilities at your science center?
    b. Are others also responsible for DEI at your institution?

c. What are the DEI related tasks, duties, and responsibilities for other positions at your institutions?

5. What are the challenges to implementing DEI at your institution?

    d. What self-development challenges do you experience when implementing DEI?

    e. In your opinion, do you think these challenges are found only at your institution, or are they a wider set of challenges across institutions?

    f. Why do you believe these challenges exist?

6. What is your institution's DEI focus by diversity category?

Cultural Relevance

7. Description of culturally relevant principles in education.

    a. Have you heard of CRP or CRE?

    b. How would you describe CRE?

    c. What are the goals of CRE?

    d. How would you know if someone was using CRE in their practice?

8. What do you think about cultural relevancy in informal science education?

    e. How do you perceive the role of cultural relevancy in science centers?

Culturally Relevant Practices

9. Please tell me about the use of CRE at your institution.

    a. Do you use CRP or CRE in your institution?

    b. How do you apply culturally relevancy at your science center?

    c. How do you use CRP or CRE in your institution (program development, program delivery, exhibits, etc.)?

    d. Do others at your institution use CRP or CRE (if so, what positions and how)?

10. If you could explain to someone who is a new science center educator, how to use CRP or CRE at the science center, what would you tell them to change?
11. How do you think audience/visitor learning is impacted when you use CRP?

General Probes

1. I am really interested in hearing more about________ (asking for more details)
2. Ok, that is really interesting, how would you say it applies to_______ (asking for application or extension).
3. Ok, thanks. Can you see how it might connect to______ (redirect)

Appendix D

Framework to Instrument

A Priori Code	**CRE markers** (Dover, 2013)	**CRE Statements** (Aronson and Laughter, 2016; p. 167)	**Category of Interview Questions**	**Interview Question** *(Brown et al., 2019) **(Busch et al., 2022)	**Interview Probes**	**Research Question Alignment**
AS&C	Academic skills and concepts	"Culturally relevant educators use constructivist methods to develop bridges connecting students' cultural references to academic skills and concepts. Culturally relevant educators build on the knowledges and cultural assets students bring with them into the classroom; the culturally relevant classroom is inclusive of all students."	Culturally Relevant Practices	Please tell me about the use of CRE at your institution.	a. Do you use CRP/CRE in your institution? b. How do you apply culturally relevant principles at your science center? c. How do you use CRP/CRE in your institution (program development, program delivery, exhibits, etc.)?* d. Do others at your institution use CRP/CRE (if so, what positions and how)?	RQ3
				If you could explain to someone who is a new science center educator, how to use CRP at the science center, what would you tell them to change?*	General probes	RQ3
				How do you think audience/visitor learning is impacted when you use CRP?*	General probes	RQ1
CR	Critical reflection	"Culturally relevant educators engage students in critical reflection about their own lives and societies. In the classroom, culturally relevant educators use inclusive curricula and activities to support analysis of all the cultures represented."	Cultural Relevance	Please offer an explanation of what you know about culturally relevant principles in education.*	a. Have you heard of CRP or CRE? b. What is CRE?* c. How does CRE work?*	RQ1
				What do you think about cultural relevancy in informal science education?	a. How do you perceive the role of cultural relevancy in science centers?	RQ2
CC	Cultural competence	"Culturally relevant educators facilitate students' cultural competence. The	Institutional Culture	What is the culture of the science center where you currently work?	a. How do you define culture? b. Is the culture of a person or group of people defined differently than the culture of an institution? c.	RQ3

A Priori Code	**CRE markers** (Dover, 2013)	**CRE Statements** (Aronson and Laughter, 2016; p. 167)	**Category of Interview Questions**	**Interview Question** *(Brown et al., 2019) **(Busch et al., 2022)	**Interview Probes**	**Research Question Alignment**
		culturally relevant classroom is a place where students both learn about their own and others' cultures and also develop pride in their own and others' cultures."			How would you escribe your own culture (background, family, religion, food, clothes, music, mood)? d. How would you describe the culture of the science center where you work if you were more descriptive and less value laden?	
CDP	Critique discourse of power	"Culturally relevant educators explicitly unmask and unmake oppressive systems through the critique of discourses of power. Culturally relevant educators work not only in the classroom but also in the active pursuit of social justice for all members of society."	Institutional Diversity, Equity, and Inclusion	Tell me about DEI related responsibilities at the science center where you currently work.	a. What are your DEI related responsibilities at your science center? b. Are others also responsible for DEI at your institution? c. What are the DEI related tasks, duties, and responsibilities for other positions at your institutions?	RQ3
				What are the challenges to implementing DEI at your institution?	a. What self-development challenges do you experience when implementing DEI? b. In your opinion, do you think these challenges are found only at your institution, or are they a wider set of challenges across institutions? c. Why do you believe these challenges exist?	RQ2
				What is your institution's DEI focus by diversity category?	General probes	RQ3
Dem.	Demographic	Background information connect perceptions with experience	Demographic	What pseudonym would you like to use instead of your name for this study?	N/A	N/A
				Tell me about your work experience as a science center educator.**	a. How many years have you been a science center educator?* b. Where have you worked?** c. In what capacity did you work for each science center? d. How were you trained to be a science center educator?**	N/A

Appendix E

Codebook

Code	Description of Code	Category	Buzz words
Audience	Science center educators center the audience when they conceptualize cultural relevancy in informal science education.	audience	audience centered, being seen, community centered, connect to audience, learner's prior knowledge
Co-Development	Science center educators conceptualize co-development as a critical part of culturally relevant education.	co-development	co-development, tool kit
Culture	Science center educators consider culture as central to culturally relevant education	culture	culture centered, education for all, gender issues, inclusive, SCE's culture
Bringing into Focus	According to science center educators, the role of cultural relevancy in informal science is to focus on the audience, make the community central, provide a mechanism to reach full potential, achieve goals, and meet science center mission, to help science centers share power with audiences and communities, and to focus science center educators on the self-work necessary to effectively reach the general public.	audience	audience engagement, impact, empowerment, connect with, serve, prioritize audience, generate mutual respect
		community	center/focus on community, intentionally center culture
		mission	help define/support science, science center mission/goal, build public science knowledge & trust, points to next steps--science action, in step with educational trends
		powersharing	powersharing/co-development
		self work	self reflection/correction
		language	language accessibility

Code	Description of Code	Category	Buzz words
Key Component	According to science center educators, cultural relevancy plays an integral role in science centers, contextually as well as programmatically including building educational structures that model inclusive behaviors such as empathy and curiosity.	integral	integral part of science center, physical space
		modeling	encourage, teach, demonstrate empathy, modeling behavior & pedagogy
Barriers: Alienate communities	Community alienation is a barrier to applying culturally relevant principles in science centers.	alienate communities	communities feel uncomfortable and unwelcomed, cost excludes some communities, DEI solutions not applicable across all communities, community contribution undercompensated/ undervalued, institution doesn't reflect local community
Barriers: fragility	The perception of fragility is a barrier to applying culturally relevant principles in science centers.	fragility	conversation makes people feel bad, problem is overwhelming / immobilizing
Barriers: personnel problems	Personnel-related issues create barriers that inhibit the application of culturally relevant principles in science centers.	personnel problems	board out of touch, all White staff can't portray diversity, staff changes inhibit DEI, hiring practices inhibit DEI, lack of staff diversity, staff inequality, staff lack knowledge / training, staff perpetuate non-inclusive culture, DEI responsibility siloed, staff lack authority and accountability, staff turnover
Barriers: systemic	Barriers to applying culturally relevant principles are systemic to science centers and pervasive industry-wide.	systemic	DEI unclear, DEI practices ambiguous, industry-wide structural issues, racism, Whiteness of science centers is an industry-wide barrier, shallow (skin deep) changes keep old structures, lack of DEI framework for ISE institutions, funding for staff development, time and funding capacity
Supports: reinforce staff	Support the application of culturally relevant principles in science centers by reinforcing staff.	reinforce staff	DEI focus hiring process, Staff development. training

Code	Description of Code	Category	Buzz words
Supports: co-construction	Co-constructing with the community supports the application of culturally relevant principles in science centers.	co-construction	co-construction of programs, grant collaboration, partnerships, importance of process, process-centered, community centered, people first
Supports: allocate time	Allocating time for DEI supports the application of culturally relevant principles in science centers.	allocate time	allocation of time, prioritize DEI
Ideal Practices: DEI hiring techniques	Incorporating DEI-related hiring techniques is an ideal practice to improve culturally relevant education (CRE) in science centers.	DEI hiring techniques	hire for skill not education, skills over degrees, hire racial diversity
Ideal Practices: centering CRE	Centering CRE, by focusing on educators' experiences, knowing the audience, and developing and implementing DEI tool sets, is an ideal practice to improve culturally relevant education in science centers.	centering CRE	center educators' experiences, local audience reflect exhibits, audience centered, CRE foundational, CRE centered; redefine science, DEI tools, culture of reflection, do CRE work; plan in advance, conscious of euro-centric timeline; develop content with cultural audience
Ideal Practices: CRE-related training	CRE-related training is an ideal practice to improve culturally relevant education (CRE) in science centers.	training	DEI training, training with shadowing, use examples, training with learning concepts, CRE professional development, formal education, scaffold DEI training, what to teach educators, educators collaborators, educators listening
		selective training only	only introduce DEI to experienced educators, educators collaborators, educators listening
Current Practices: acting as barriers	Some of SCEs' and ISE institutions' current practices act as barriers to applying culturally relevant principles in science center.	current practices that are barriers	CRE term not used, theory to practice gap, inadequate or no CRE practiced, institution needs to do more related to CRE, DEI not supported by institutional strategy, CRE or DEI is personal initiative of individual staff

Code	Description of Code	Category	Buzz words
Current Practices: educator focused	Some of SCEs' current practices related to applying culturally relevant principles in science centers are educator focused.	educator focus practices	asking audience questions, what educators are doing with audiences, educators start with themselves, educator's cultural capital, internal listening groups, internal communities-museum audience staff
Current Practices: institutional initiatives	Some of SCEs' current practices related to applying culturally relevant principles in science centers are institutional initiatives.	institutional initiatives	uses CRE in programming, DEI impacts exhibits, institution's DEI focus (language, race, socioeconomic, or it is not clear), diversity audience officer, DEI supported by institutional strategy, partnerships, grants, traveling exhibits, industry practices (outside of the institution)
Current Practices: societal driven	Some SCEs' current practices related to applying culturally relevant principles in science centers are driven by contemporary societal issues.	societal driven practices	racial reckoning, police violence, murder of George Floyd, COVID impact, science connected to social issue (climate change, science denialism)

Appendix F

Examples of Participants' Descriptions of Culture

Participants' Pseudonym	Definition of Culture	Description of Institution's Culture	Description of Own Culture	Own Culture Category
Bekka	"It's explicit or implicit, felt, seen words, actions, policies. The way the culture is experienced, the way the institution is experienced by the community."	"So many single words pop into mind. First one is just dysfunctional. Our internal culture of the museum, which often has some type of hierarchical pecking order, has groups of people feeling that they're the least of the bunch. You've got your floor educators that just get dumped on."	As an individual I'm not sure I necessarily have culture, because I do think culture is kind of built a from community. This is a hard question, actually I like where you're going with this because, I reflect on the fact that I don't really have a strong culture identify, so then, how would I identify with students or visitors that I work with if they have strong cultures that they do identify with?	No culture but an epiphany
Catherine	"Culture is something that's built by the people that are working together and living together so it's all the people in the city it's all the people that are working together it's all the people that are living together."	"We are a museum in a kind of isolated big town in the middle of rural [Midwestern state] so it's a relatively large city, but it's surrounded by a lot of farms."	"I come from very White America, Midwest White America, but also very poor group of family, so I have seen some of the struggles of the families that I work with, and so I have the advantages of being white, CisHet female, but I also came from a very poor family that was getting free lunches growing up and struggled in that way"	Comprehensive - race & socioeconomic status
Dio	"It's how people interact with one another, or what is the vibe is like. Do people feel comfortable? This culture also can have another meaning geared towards one's race or ethnic background. So I do think that there's multiple definitions, based on the context."	"Pre pandemic, people felt comfortable reaching out to many of the educators or the floor scientists, we had many interactive labs where scientists were able to talk directly to visitors. It really it really helped to break down that barrier between the general public and scientists."	I am a black American male raised in [southeastern US] and have lived in [the southeastern US] my entire life and so I have lots of southern roots Black culture growing up in a Black churches And it has Informed a lot of facets of my life	Comprehensive - Race

Participants' Pseudonym	Definition of Culture	Description of Institution's Culture	Description of Own Culture	Own Culture Category
Ir	"Culture is the kind of feelings and dynamics of a community or group of people."	"We have a good Community, and we're working towards being better. Especially over the past year and a half, we've really tried to grow as a community to be even more inclusive an understanding. We really want to work to represent our community. And so that's been kind of a mission of the museums."	That's a great question, the culture that shapes me is whiteness. I believe that American culture in general is a culture of White supremacy and I think that that's something that comes through, even though I want it to be a good thing. I feel like as a White person, white is not an ethnicity, it's a cultural blob. I feel like White culture is this kind of big hegemonic idea that's based on power more than it is on the history of a particular region	White supremacy
Marie	"Culture is the traditions, the norms the shared understanding the way we do things that groups of people create."	"In flux. Thinking about how staff at the front are treated and the division between what is thought to be the upstairs management and the downstairs everybody. And also, knowing that most of my co-workers in positions of power are White. The leadership of the organization is completely White."	My personal culture? How do I describe my own culture? Um, it's interesting, I've never particularly thought about.	None, uncertain, or ambivalent