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Promoting Social Sustainability: Implementing A Dynamic Stem Driven Framework To Empower Underrepresented Communities In West Texas Schools

Raquel Haggerty
University of Texas at El Paso

PROMOTING SOCIAL SUSTAINABILITY: IMPLEMENTING A DYNAMIC STEM DRIVEN FRAMEWORK TO EMPOWER UNDERREPRESENTED COMMUNITIES IN WEST TEXAS SCHOOLS

RAQUEL HAGGERTY

Doctoral Program in Environmental Science and Engineering

APPROVED:

Peter Golding, Ph.D., Chair

Diane Golding, Ph.D.

Luis G. Perez, Ph.D.

Luis Rene Contreras-Sapien, Ph.D.

Scott Starks, Ph.D.

Annalisa Perez, Ph.D.

Stephen L. Crites, Jr., Ph.D.
Dean of the Graduate School

Dedication

As my grandmother wisely said, "Each contribution, no matter its size, like grains of sand, accumulates into something significant—not by the number of acts, but by the love each one carries." So, thank you to each family member because you each contributed in some way towards my journey of achieving this degree.

The phrase "¡Sigue Adelante!" resonates in my mind to this day, a legacy of my grandparents, Guadalupe and Carlos Estrello. They immigrated from Mexico nearly 70 years ago seeking better opportunities for their future generations. Observing their resilience, work ethic, and deep love for family taught me that even if we're scared of challenges, we face them regardless because we know He who goes before us. My grandmother, a source of strength, often concluded her comforting words with "¡Sigue Adelante!" as she always pushed us to do our best, embodying perseverance and the most genuine love anyone could ever experience. This degree symbolizes not just an academic achievement but honors the sacrifices of my grandparents, who ventured far from home, so we could have a better life. I strive to make them proud. We truly live in the greatest country in the world and for that I am forever grateful! My parents and extended family have shaped me into who I am today. Their collective spirit is woven into my very essence, driving my life's work. The support of my loving parents, brothers, aunts, uncles, grandparents, and cousins have always inspired me, a role now shared with my nieces, nephews, little sister, and sons. To my Mom and Dad Brian, you have always been my pillars of support and encouragement, no matter my choices. Thank you for that! My brothers Art & Michael, I admire you. Dad Art and DeeDee, thank you for the gift of a new chapter. To my husband Shane, you are God's blessing to me! Thank you and I love all of you, with **ALL** my heart.

¡Sigue Adelante!

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by

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Reflecting on a career assessment given by my middle school counselor in the late 80's, I still find it amusing that the computer suggested I become either a priest or a lumberjack! It seemed to misunderstand my passion for math and science as inclinations for traditionally male-dominated fields. Ignoring such stereotypical advice became a habit for me. Instead, I pursued my passion, supported by many who believed in me. This journey not only shaped my career but also, I hope, has paved the way for others, proving that passion and determination can lead to unexpected and rewarding destinations.

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Abstract

This dissertation explores how environmental engineering can utilize STEM education as a strategic tool, enhancing social sustainability and thereby empowering underserved Hispanic communities in West Texas. Responding to significant educational and resource disparities, this research introduces an innovative interdisciplinary framework that combines instruction-initiated resource activation (I2RA), culturally attuned parent engagement (CAPE), and community-centered STEM education (CCSE). This approach uniquely addresses the challenges faced by these communities, integrating environmental solutions with educational advancements to forge a path toward equitable STEM access and achievement.

Additionally, the "Elevate and Empower" case study exemplifies the practical application of this comprehensive framework, demonstrating its effectiveness in enhancing STEM education outcomes and narrowing the educational and social divides. Furthermore, this research highlights the framework's potential to catalyze policy-driven change, advocating for continued innovation and collaboration in engineering solutions for social sustainability and community empowerment. Placing environmental engineering at the center of societal progress, this study aims to demonstrate how targeted STEM educational initiatives can lead to significant social and environmental improvements.

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Preface

The distinct smell of burning metal filled the air as I ran through the Engineering building at The University of Texas at El Paso (UTEP) to get to class. A million questions were running through my head, such as, "What is metallurgy?", "What kind of name is Dr. Fisher?", or, more surprisingly, "I'm only 13 years old, what am I doing here with college students?" It was 1989, and I had been selected by my Algebra teacher to attend an 8-week summer engineering program at UTEP called the "Texas Pre-freshman Engineering Program (TexPREP)". It lasted three consecutive summers, and each one contributed towards the foundation of my future success. The inspiration I received, along with my self-motivation and determination, created a path that continues advancing to this day.

While pursuing my undergraduate degree in engineering at UTEP, I began tutoring and that's when I realized my life's mission. I could graduate and become one engineer in the world or I could teach engineering to young students and inspire hundreds, maybe even thousands, of young engineers to go out and change the world. My passion was ignited that day and it's only grown stronger with time. Upon graduation, I began teaching 6th grade Math at an elementary school in the neighborhood I grew up in. This held deep significance for me, as the neighborhood falls within a socioeconomically disadvantaged area, and I aimed to contribute to my community in a way that mirrored the impact the TexPREP program had on me. My community might be poor financially, but it is rich in talent and potential, so I made it my life's mission to inspire the children in my community to pursue engineering.

My journey of empowering economically underserved Hispanic communities in West Texas through STEM education and community engagement is deeply rooted in this personal experience and drives my commitment to fostering positive change. It overwhelmingly ignited my

passion for both engineering and education. This experience laid the foundation for my future, leading to a mission that transcended being just an engineer to becoming an educator who could inspire countless young minds to shape the world.

Transitioning into the role of an educator during my undergraduate years, I discovered a profound calling to bridge the gap in STEM education for underrepresented communities. This calling led me to establish an elementary after-school engineering club. Over the next decade, it evolved into a Texas Education Agency-designated middle school T-STEM engineering program, offering students high school credit. Despite operating with minimal resources, the program flourished, resulting in numerous awards and accolades at local, state, and national STEM competitions. My dedication extended beyond academic achievements as I championed female representation in STEM through the creation of an all-girl team named Girl P.O.W.E.R., which stood for "Preparing Outstanding Women for Engineering Roles."

Within the challenging context of a Title 1 school, my students defied the odds to achieve extraordinary success. From winning technology and robotic competitions to being recognized at the White House, their achievements showcased the transformative power of comprehensive STEM education. Through volunteering, grant writing, and advocacy, I ensured that my students had exposure to cultural enrichment and opportunities that extended beyond the classroom. Additionally, recognition as Teacher of the Year for Region 19 and renaming of my school to Parkland Pre-Engineering Middle School marked milestones in advancing STEM education in my community. I shared my expertise with fellow educators, fostering a network of empowered STEM teachers committed to nurturing the next generation of innovators. Despite these accomplishments, the multifaceted nature of STEM programs in the community revealed discrepancies and missed opportunities in providing a holistic STEM education.

Recognizing the need for a standardized and community-specific STEM curriculum, I embarked on a journey to pursue a Master's degree in Curriculum and Instruction in STEM Education. The knowledge gained from this undertaking equipped me to develop impactful curricula and contributed to my lifelong goal of creating a kindergarten-through-college vertical pipeline to support local STEM needs.

As my passion grew, I transitioned to the UTEP Aerospace Center in 2023, assuming the role of K-12 Program Manager. In this capacity, I help create STEM education pathways, connecting underrepresented students with aerospace industry research opportunities, and guide them toward STEM careers. The results of this program are already evident in increased student engagement and student choices to pursue STEM disciplines at UTEP.

The journey to empower economically underserved Hispanic communities in West Texas, reported in this dissertation, is a testament to the transformative potential of instruction-initiated resource activation, culturally attuned parent engagement, and community-centered STEM education. The experiences shared here underscore the need for an interdisciplinary framework promoting community empowerment throughout areas of West Texas that need it most, and the subsequent sections analyze the research, insights, and implications of this framework leading to a more sustainable and empowered future.

Chapter 1: Overview

1.1 INTRODUCTION

This research aims to showcase the significant role of environmental engineering in empowering disadvantaged communities by promoting social sustainability through targeted STEM education strategies. These communities often lack the necessary resources and sustainable support systems to promote educational achievement and success in the STEM field. To empower these communities, this research investigates the impact of three supportive components; instruction-initiated resource activation (I^2RA), culturally attuned parent engagement, and community-centered STEM education as a framework for sustainable community empowerment. Addressing these educational STEM disparities through the lens of environmental engineering offers a unique opportunity to not only enhance STEM education but also to contribute to social sustainability and community empowerment. Environmental engineering, with its focus on sustainable solutions to societal challenges, provides a critical context for applying STEM education as a tool for community development.

According to Valentine et al. (2020), community empowerment refers to the process of enhancing the capacity, skills, knowledge, and resources of individuals and groups within a community's environment to take control over their lives, address their needs, and achieve their goals. Likewise, it involves promoting participation, collaboration, and decision-making power among community members to create positive change and improve their well-being. Therefore, through the implementation of the first component, (I^2RA), STEM educators can leverage the existing strengths and resources within the community to support educational STEM initiatives beyond that available in the traditional classroom. This study will explore how everyday challenges, such as parents working multiple jobs or facing language barriers, impact parental

involvement. It seeks to challenge the misconception that Hispanic families with lower economic resources are not engaged in their children's education. Far from being disengaged, these families often exhibit unique forms of participation deeply rooted in their cultural values, where family plays a central role in providing support. This investigation seeks to highlight the importance of recognizing and embracing these distinct contributions as essential to the educational STEM ecosystem. By implementing purposeful strategies such as accommodating work schedules, offering materials in native languages, and guiding parents on supporting STEM education, educators can enhance family-school collaboration in these underserved areas. Acknowledging Hispanic families as crucial pillars of support not only bridges the educational divide but also empowers these communities, reinforcing the family's inherent role as a critical support system in fostering educational STEM success.

The framework's third component integrates community-centered STEM education and is designed to equip students with the skills and knowledge necessary for thriving in an ever-evolving technological landscape. Incorporating partnerships with STEM-related businesses, organizations, and universities offers students access to a wealth of practical resources, including opportunities for job shadowing, mentorship, and tackling real-world engineering challenges. Such exposure enriches their educational STEM experience and bridges the gap between theoretical knowledge and its practical application. This prepares students to contribute effectively to the engineering profession and address societal needs through innovative solutions.

1.2 Problem Definition

The challenges presented stress the difficulties faced by economically underserved Hispanic communities in West Texas as they strive to access quality STEM education and equitable STEM opportunities. The application of this research was primarily centered in both

El Paso and Presidio Counties. According to the U.S. Census Bureau (2022), the data reveals that the average per capita income in El Paso County is $26,011, while in Presidio County it′s a mere $22,256, which is significantly lower than the national average of $41,261. The poverty rate in these two West Texas counties is double that of the U.S., further deepening the challenges faced by residents. Additionally, only 25% of individuals in El Paso and 21% in Presidio hold college degrees, compared to 34% nationally. Given that both El Paso and Presidio counties have a Hispanic population of 83%, significantly higher than the U.S. average of 19%, it is evident that this demographic group is disproportionately affected and forms a significant focus of impact. These statistics highlight the socioeconomic disparities and educational barriers prevalent in these communities, emphasizing the urgent need for investigation. Exploring how environmental engineering, combined with targeted STEM education strategies, can serve as a tool to promote social sustainability and help empower disadvantaged populations is essential. Therefore, this research explores three critical problem areas:

1. Lack of Comprehensive Studies: The research revealed a notable gap in comprehensive studies that investigate the role of instruction-initiated resource activation and culturally attuned parent engagement as drivers of community empowerment within economically underserved Hispanic communities in West Texas. Existing literature acknowledges the importance of STEM education initiatives and community engagement but lacks holistic exploration of how these elements collectively contribute to the notion of empowerment as it relates to education in the field of STEM. Additionally, for students and parents in El Paso and Presidio counties who face language barriers, such as limited English proficiency, accessing STEM education resources and opportunities can be particularly challenging. The intersection of language barriers with limited access to educational resources, such as

advanced STEM courses or extracurricular activities, can further hinder academic success and participation in STEM-related fields. Culturally responsive approaches that provide language support and equitable access to resources are crucial in addressing these intersectional challenges.

2. Social Context and Barriers: The analysis of research reveals the significance of addressing social barriers and promoting inclusivity in STEM education. Interventions aimed at altering educational policies or societal views have positively impacted students' motivation and attitude toward STEM subjects. For example, Hispanic girls in STEM fields may face unique challenges due to societal stereotypes, cultural expectations, and gender biases that intersect with their ethnicity. These intersecting identities can influence their confidence, access to resources, and opportunities for advancement in STEM education and careers (Chen et al., 2022) (Falco & Summers, 2017) (Garibay, 2022) (MacPhee et al., 2013). Addressing these intersectional barriers requires targeted interventions that recognize and support the specific needs of Hispanic students in pursuing STEM fields. The intersection of cultural norms within Hispanic communities and socioeconomic status can impact students' perceptions of STEM education and career pathways. In some cases, cultural values or economic constraints may influence educational aspirations, career choices, and access to STEM-related opportunities. Understanding how these intersecting factors shape individuals' attitudes towards STEM and their educational trajectories is essential. It allows for the design of inclusive and empowering STEM initiatives that align with the cultural backgrounds and economic realities of students in El Paso and Presidio counties. Engaging community stakeholders, such as parents, local businesses, universities,

and government agencies, has been shown to enhance the effectiveness of integrated STEM education (Avendaño et al., 2018) (Luecke et al., 2023).

3. Need for Holistic Approach: A holistic strategy is imperative to support these communities effectively, calling for initiatives that harness the catalytic potential of STEM educators, encourage parental involvement, and address the unique community needs. This research advocates for an interdisciplinary framework that integrates environmental engineering principles with dynamic STEM education methodologies to foster sustainable community development and empowerment.

Addressing these issues requires a unified approach to develop sustainable solutions that assist to empower these communities, underscoring the need for an interdisciplinary approach that intersects environmental engineering concepts with targeted STEM education strategies. This research aims to contribute substantively to social sustainability by tailoring educational interventions to the specificities of economically underserved Hispanic communities in West Texas, leveraging a comprehensive analysis of their socioeconomic and educational landscapes.

1.3 Research Objectives

1. Develop and implement an interdisciplinary Community Empowerment Framework that leverages STEM education and environmental engineering principles to enhance social sustainability and empower underserved Hispanic communities in West Texas, aiming for equity in STEM education among underrepresented populations.
2. Enhance the STEM educational environment for underrepresented students by creating a supportive community and effectively organizing resources, with a focus on facilitating parental involvement and leveraging local partnerships in West Texas schools.

3. Formulate actionable strategies that integrate environmental engineering principles and culturally attuned initiatives into STEM education, focused on achieving sustainable community development and empowering economically disadvantaged communities through applied learning and practical engagement.

By focusing on these objectives, this research aims to demonstrate how environmental engineering, through targeted STEM education approaches, can play a pivotal role in fostering community empowerment and advancing social sustainability. Focusing on preparing culturally responsive STEM teachers involves redefining parent engagement according to community perspectives. Implementing community-engaged programs enables STEM educators to collaborate closely with community members linked to local STEM related business sectors. This approach offers a chance to challenge traditional notions of knowledge and expertise, as well as disrupt conventional and institutional boundaries in STEM education.

1.4 SCOPE

1.4.1 Geographical Scope

This study will concentrate on the economically underserved Hispanic communities in West Texas, such as El Paso with a specific case study focus on Presidio schools near the Rio Grande River. These areas have been identified as having a low socioeconomic status and high poverty rates, which are known to contribute to academic inequities in STEM education (Avendaño et al., 2018). Given the pressing need to empower these communities, El Paso and Presidio serve as pivotal research sites, representing the broader challenges faced by similar Hispanic communities in the region. The chosen geographical scope not only aids in understanding the local STEM related educational disparities but also showcases the potential of

instruction-initiated, culturally attuned, and community-centered interventions to reshape educational STEM outcomes in comparable contexts.

1.4.2 Stages of the Instruction

There are three stages of instruction that include elementary, secondary, and higher education. The proposed framework is applicable at all stages; however, the focus of this research will be on the incoming higher education stage.

1.4.3 Components of the Integrated Interdisciplinary Approach

Each component, instruction-initiated resource activation, culturally attuned parent engagement, and community-centered STEM education, while impactful individually, is especially powerful when viewed through the lens of environmental engineering. This perspective enables a holistic understanding of how these components can collectively drive improvements in social sustainability and empowerment. The scope includes understanding how these components work together to drive improvements in community empowerment.

1.5 AIM

This research develops an interdisciplinary framework that integrates instruction-initiated resource activation, culturally attuned parent engagement, and community-centered STEM education, aiming to improve STEM access in economically underserved Hispanic communities in West Texas and promote community empowerment. It will explore effective strategies and outcomes for sustainable development and equitable STEM educational access. Additionally, the study will assess the integrated approach's impact within Environmental Science Engineering, focusing on empowerment and sustainability, while highlighting a few of the community challenges, opportunities, and areas needing STEM support.

As environmental challenges increasingly demand innovative responses, the role of an interdisciplinary STEM education framework within these communities becomes vital. This research not only seeks to evaluate the effectiveness of such an approach in the STEM field, but also emphasizes its critical contribution to fostering community empowerment and sustainable development. Further investigation into the interdisciplinary model will not only bolster the socially sustainable concept of community empowerment but also equip these communities to address this environmental issue more effectively.

1.6 Additional Factors

The evaluation will shift towards additional factors shaped to empower predominantly Hispanic communities in West Texas through the realm of STEM education. By scrutinizing the combined impacts of instruction-initiated resource activation, culturally attuned parent engagement, and community-centered STEM initiatives, the objective is to reveal the transformative potential of these approaches in developing sustainable community empowerment and educational STEM resource equity. Through a collaborative and STEM inclusive perspective, the underlying factors driving positive change and holistic growth within these underrepresented communities will be explored.

1.6.1 Empowerment and measurable improvements

This study explores the impact of an interdisciplinary approach on community empowerment and identifies ways to measure its effectiveness. It is essential to define what empowerment means within the context of this study and establish methods for assessing it. This dissertation defines community empowerment as enhancing the capabilities, skills, and resources of individuals and groups within a community to take control over their lives, address their needs, and achieve their goals. It emphasizes promoting participation, collaboration, and decision-making

power among community members to create positive change and improve their well-being. By doing so, we can better understand how this approach contributes to measurable improvements in empowering communities (Valentine et al., 2020) (Hurk et al., 2018). Detailed analyses will be presented in Chapter 6.2, focusing on Step 1.

1.6.2 Addressing barriers

This project's scope involves identifying and understanding the barriers that hinder equitable access to STEM opportunities within the underserved community. These barriers may include financial, educational, cultural, or other challenges that must be addressed to promote greater equity and inclusivity in STEM education. Furthermore, the study explores how the tailored interdisciplinary approach addresses these barriers and works towards creating a more STEM inclusive and empowering environment for the community (Avendaño et al., 2018).

1.6.3 Sustainable community development

This study will evaluate the impact of the interdisciplinary approach on supporting community development as a result of establishing a sustainable framework. It will examine the lasting effects of this approach on the educational, social, and economic aspects of the community as it relates to STEM education, using a combination of surveys, academic performance data analysis, interviews, and community feedback sessions. Moreover, insights gathered from this research could serve as a blueprint for other communities striving to achieve sustainable growth and empowerment through STEM education. Su & Jagninski (2013) emphasize that STEM education, when integrated with community partnerships and experiential learning, can serve as a powerful tool for promoting sustainable community development. By engaging marginalized youth in STEM-related projects and empowering them to contribute to their communities, STEM education becomes a catalyst for positive change and long-term sustainability in local

neighborhoods (Su & Jagninski, 2013) (Valentine et al., 2020). Therefore, by assessing the lasting effects of this integrated approach, we can determine its effectiveness in promoting sustainable community development.

1.6.4 Key components and mechanisms

This research will examine the underlying components and mechanisms that contribute to the observed improvements. This investigation identifies these key components and gains a comprehensive understanding of how they function within the context of the interdisciplinary approach. By identifying these key components and tools, we can gain understanding into the particular components of the integrated approach that contribute to empowering communities in STEM education (Nugent et al., 2015).

1.6.5 Data collection

To gather comprehensive insight into the experiences, perceptions, and outcomes related to the integrated approach in STEM education, a variety of qualitative data collection methods were employed. These methods included interviewing students, parents, and teachers, observing classroom environments, engaging in STEM related community events, and significantly, tracking the number of college applications for majors in STEM fields. The collected data will be studied using educational analysis to identify patterns, themes, and connections within the data.

The comprehensive strategies help develop resource tools that deliver effective results in supporting and promoting students to enter STEM fields. Additionally, this study will feature a case study on a West Texas STEM camp and examine the subsequent number of university applications submitted by its participants. This aims to highlight the beneficial effects of a well-structured framework in increasing student involvement into STEM fields and its influence on various stakeholders. Drawing from diverse sources, including students, parents, and teachers,

ensures a comprehensive understanding of the intricate dynamics of the integrated approach. By analyzing these diverse experiences and viewpoints, the research addresses potential avenues for refinement and further innovation in the approach and delivery of STEM education.

1.6.6 STEM equity and inclusion

The interdisciplinary approach is examined in terms of its impact on traditionally marginalized groups within the community, emphasizing the importance of STEM equity and inclusion. Recognizing the disparities these groups face, the study aims to discern whether the interdisciplinary approach effectively narrows the STEM related educational and opportunity gaps for students. Furthermore, it will evaluate the approach's potential to foster a more inclusive environment where all members of the community feel valued and empowered to participate fully in STEM activities and learning (Avendaño et al., 2018).

1.6.7 Educational and social context

The study examines the educational context of STEM culture in the community, as well as broader social and economic factors that affect community empowerment. By analyzing the intertwined relationships between educational STEM practices, societal influences, and economic conditions, a clearer picture of the challenges and opportunities within the community will emerge. This multifaceted exploration will not only provide a deeper understanding of the existing infrastructure but also shed light on potential areas of STEM intervention and support (Hachey et al., 2021) (Nugent et al., 2015) (White et al., 2019).

The effectiveness and sustainability of integrated STEM education in the community is an important topic to consider. Numerous studies have been conducted on this subject, exploring various aspects such as social context, student attitudes toward science and engineering, and the integration of different STEM disciplines. The findings from these studies contribute valuable

insight into the benefits and challenges associated with implementing integrated STEM approaches in educational settings. In examining these additional factors, this interdisciplinary approach leverages environmental engineering as a foundational pillar for driving sustainable community development and educational STEM equity. This interdisciplinary combination demonstrates the transformative potential of engineering solutions in addressing complex social challenges.

1.7 CONCLUSION

As we conclude Chapter 1, we have established a foundational understanding of the disparities in STEM education within economically disadvantaged Hispanic communities in West Texas, supporting the imperative need for innovative solutions. This initial exploration sets the stage for a deeper investigation into how environmental engineering principles, coupled with STEM education, can be strategically utilized to foster social sustainability and empower these underserved communities.

This research is uniquely positioned at the intersection of environmental engineering and education, aiming to harness the transformative power of STEM as a tool for community development. The interdisciplinary framework that will be thoroughly presented in later chapters encompasses instruction-initiated resource activation, culturally attuned parent engagement, and community-centered STEM education, embodies the commitment to leveraging environmental engineering strategies to build resilient and empowered communities.

As we transition into Chapter 2, the focus will turn to the theoretical frameworks that inform this approach of integrating STEM education with environmental engineering practices towards enhancing social sustainability. The literature review will investigate into existing research on environmental engineering solutions that address social challenges, the role of STEM education in equipping disadvantaged communities with the necessary skills for sustainable

development. It will also explore the cultural perspective of Hispanic parental engagement and examine models of community empowerment that have been successfully implemented. By examining these areas through the lens of environmental engineering, we aim to identify gaps in current educational STEM practices. This analysis will highlight opportunities where STEM education can significantly contribute to achieving social sustainability goals.

Chapter 2: Literature Review

2.1 INTRODUCTION

In the evolving landscape of Environmental Science Engineering, ensuring STEM education accessibility for underserved communities becomes crucial for fostering a future rooted in social sustainability. By integrating principles of STEM education, spanning science, technology, engineering, and mathematics, along with the innovative approaches of environmental engineering, this study aims to highlight pathways toward a more sustainable and equitable future for underserved communities.

This literature review explores the existing works at the intersection of these fields, aiming to highlight the crucial role of community empowerment in advancing environmentally conscious initiatives. At the center of this empowerment lies the role of STEM educators, parents, and the broader community framework. The following literature review sheds light on the need for an interdisciplinary approach that not only helps to bridge the educational disparities in STEM but also reinforces community resilience and influence. As we navigate through the subsequent subchapters, we will better comprehend the intricate connections between STEM education and the two pivotal aspects of environmental engineering: social sustainability and community empowerment. This research will reveal how these interconnected components collectively foster a more sustainable and equitable future for students in STEM fields by helping to support and strengthen a vertical pipeline of aspiring engineers.

We will explore the critical role that STEM education plays within the expansive framework of environmental engineering, highlighting its indispensable contribution to creating solutions that not only address environmental concerns but also foster a sense of empowerment among underserved communities. Central to this exploration is the recognition of STEM

education as a tool for empowerment, particularly within communities that have historically been marginalized and underserved.

The significance of this study is particularly pronounced in the context of enhancing social sustainability. Through a comprehensive examination of STEM education initiatives, this research demonstrates the potential of engineering solutions to catalyze significant advancements in social equity and environmental stewardship. The capacity of STEM education to inspire, engage, and equip individuals with the skills necessary to tackle environmental challenges is unparalleled.

Moreover, the relevance of this study extends beyond academic discourse, touching on practical implications for engineering solutions aimed at enhancing social sustainability. By bridging the gap between theoretical knowledge and real-world applications, the study endeavors to showcase the transformative power of STEM education in engineering contexts, particularly its role in devising solutions that are both environmentally sound and socially inclusive. Through this research, we aim to highlight the essential role of an interdisciplinary approach in addressing the environmental challenges of our time, ultimately contributing to the creation of more sustainable and equitable communities, ensuring they remain competitive within the national and global engineering landscape.

2.2 Background and Theoretical Framework

2.2.1 Environmental Science Engineering and Social Sustainability

The integration of environmental science engineering with the goals of social sustainability forms a cornerstone of modern engineering practices. Through the lens of environmental science engineering, the principles of sustainability are not merely about conservation but also encompass social equity and community resilience. According to a study by Ashton et al. (2022), there is a call for the integration of environmental science engineering with social sustainability goals. This

integration displays the importance of engineering solutions in promoting social equity, community resilience, and justice. Ashton et al. findings show that utilizing engineering solutions, including cutting-edge technologies and sustainable methodologies, offers a way to tackle environmental challenges effectively. Such innovative approaches in engineering can significantly enhance the social well-being of communities, ensuring that technological progress results in widespread societal advantages.

Moreover, Garibay (2015) conducted a study and discussed the perspectives of Underrepresented Students of Color (USC) in STEM fields. He mentions that many USC students in STEM have a strong commitment to working for social change compared to their non-USC counterparts. The study found that USC students in STEM majors consider working for social change more important to their career goals. Furthermore, the research indicates potential disparities in the development of social agency between USC students and non-USC students within STEM disciplines. Such findings underscore the necessity of a deeper investigation into, and the subsequent support for, the social justice outcomes for minority students in STEM education, as directly inferred from the research data.

Additionally, research by Charleston (2012) ultimately emphasizes the profound influence that the desire to give back has on fostering academic achievement, personal growth, and a deep-seated sense of social responsibility among African American students and other minorities in STEM fields. Charleston found that this encourages students to use their expertise for community upliftment and development.

2.2.2 Social Cognitive Theory and Engineering

The application of Social Cognitive Theory, within the realm of engineering education, represents a significant shift towards developing a STEM workforce capable of addressing

environmental challenges with confidence and competence. Social Cognitive Theory, developed by Albert Bandura, emphasizes the interplay between personal factors, behavior, and environment, highlighting self-efficacy as crucial in individuals' belief in their success in specific scenarios. In STEM education, this theory sheds light on the importance of self-efficacy in determining students' career choices in STEM, their persistence in overcoming academic challenges, and the role of observational learning through role models in enhancing students' skills and behaviors. By incorporating Community-Centered STEM Education, educators can leverage both self-efficacy and observational learning to improve students' academic achievements and influence their choices and resilience in STEM fields.

Lent et al. (2008) explored the long-term connections between self-efficacy, outcome expectations, interests, and the major choice goals of engineering students. Their study highlights the critical role of self-efficacy in engineering education and its influence on students' academic and career decisions within STEM fields. Their research demonstrates that enhancing students' belief in their capabilities to solve complex environmental problems encourages a proactive and solutions-oriented mindset. This approach is essential for cultivating engineering skills that are not only technical but also adaptive and innovative, capable of devising solutions that are both effective and environmentally responsible.

2.2.3 Constructivism in Engineering Research

Research by Vennix et al. (2018) suggests that a constructivist approach in STEM education equips students with critical thinking and creative skills essential in engineering. This approach, which emphasizes cultural responsiveness and community engagement, resonates with the ethical commitment in engineering to foster socially and environmentally sustainable solutions. By focusing on community-centered projects and real-world problem-solving, the constructivist

approach, as discussed by Tan et al. (2019), enhances students' engagement with complex problems that matter in their communities. Through these experiences, students develop teamwork, communication, and project management skills.

Furthermore, according to Allen et al. (2016), by engaging in inquiry-based learning and encouraging students to make meaning of their experiences, constructivism promotes a deeper understanding of real-world connections and the implications of engineering projects on society. Tan et al., (2019) emphasize the importance of learners constructing their own knowledge and understanding, rather than passively receiving information. By engaging students in real-world problem-solving and community-centered projects, the constructivist approach encourages students to explore the social, ethical, and practical dimensions of engineering projects, leading to a deeper understanding of their impact on communities

2.3 Barriers to Equitable STEM Opportunities from an Engineering Perspective

Research shows that one of the significant barriers identified within the context of underserved Hispanic communities in West Texas is the limited access to quality STEM education. This challenge is multifaceted, originating from socio-economic constraints, inadequate resources and curriculum, gender stereotypes, and insufficient culturally attuned parent engagement. All these factors fail to align with and address the unique background and needs of underserved communities as further discussed below.

2.3.1 Gender Stereotypes and Bias

Van den Hurk et al. (2018) highlight that environmental factors, including gender stereotypes within STEM, can impact a wide array of individuals, from students and teachers to study advisors, peers, family members, and prospective employers. Consequently, research by Benavent et al. (2020) reveals that girls may receive diminished encouragement and support to

excel in or opt for STEM-related educational programs and careers. Furthermore, the scarcity of female role models in STEM can reduce the sense of belonging for students considering STEM education. Research by Van den Hurk et al. (2018) has also shown that students from minority backgrounds exhibit a higher propensity for discontinuing their STEM education. This reveals the imperative for targeted interventions aimed at retaining underserved students with potential in STEM fields. Their research also discusses interventions aimed at increasing interest and persistence in STEM education, such as changing the pedagogical approach of teaching STEM, providing targeted support programs, and raising awareness about the importance of STEM education among both students and parents.

2.3.2 Lack of STEM Resources

Giuriceo & McLaughlin (2019) emphasize the critical importance of accessibility in promoting equity in STEM education, especially in the context of underfunded schools and a lack of resources. Socio-economic constraints often prevent access to high-quality STEM education, and limited diversity and representation in STEM fields present further obstacles. Moreover, the lack of innovative teaching techniques and restricted access to advanced technological tools impede progress. Giuriceo & McLaughlin (2019) also point out that implicit, systemic biases, and other contributing factors, perpetuate disparities and hinder inclusivity in STEM education. These barriers directly contribute to the underrepresentation of individuals from disadvantaged communities in STEM fields and impede their ability to fully participate and succeed in these disciplines. They also identify key logistical factors, including transportation to educational events, compatibility with students' work schedules, thoughtful location selection for events, and the mitigation of associated costs, as essential considerations to ensure these students have equal opportunities to engage with STEM activities.

Additionally, Charleston's (2012) research highlights a significant shortfall in K-12 education resources, especially for minority students, limiting their exposure to advanced computer science as well as other STEM fields. His research identifies the gap as stemming from both insufficient STEM-related curriculum and, occasionally, inadequate teaching methods. Additionally, for schools that do offer computing courses, there's a strong call to proactively recruit African American students and other underrepresented groups. This urgency is driven by shifting American demographics and the growing number of vacant computing-related positions. Thus, Charleston argues for the imperative need to more effectively prepare minority students within educational systems. This ensures their active participation in the STEM workforce, addressing educational inequities and meeting future job market demands.

Furthermore, Hachey et al. (2022) reveals the critical impact of the early educational curriculum on future academic and professional paths. The study particularly notes the significant absence of comprehensive STEM and engineering education in early U.S. public schooling. This educational gap is closely associated with diminishing student interest and proficiency in STEM disciplines, thereby influencing their capacity to cultivate substantial STEM skills in later educational stages. Hachey et al. argue the absence of early exposure to STEM and engineering not only hinders the development of technical skills but also significantly limits the diversity of perspectives and innovations within these fields.

Mau & Li (2018) detail the multifaceted challenges encountered by underserved students in STEM fields, such as diminished confidence, experiences of unfair treatment and discrimination, financial constraints, and the impact of pervasive stereotypes and biases. They advocate for a comprehensive support system, spearheaded by educational stakeholders, designed to bolster the academic, career, and personal/social development of both female and minority

students pursuing STEM disciplines. Mau & Li's call to action underscores the necessity of implementing targeted interventions and creating inclusive educational environments that not only address these barriers but also foster a culture of equity and empowerment within the STEM community.

2.3.3 Lack of Culturally Attuned Parent Engagement

Chen et al. (2022) detailed in their research that inadequate parental participation in informal STEM activities could lead to lost opportunities for students to cultivate an interest in STEM fields beyond the conventional classroom environment, which may affect their future aspirations and career decisions into STEM fields. This underscores the significance of creating a supportive atmosphere in which parents play a proactive role in promoting and guiding their children's engagement with STEM subjects and potential careers. Chen et al. research indicates active parental involvement not only enriches students' learning experiences but also lays a solid foundation for their sustained interest and success in STEM disciplines.

2.3.4 Self-Efficacy in STEM Education

Moreover, self-efficacy plays a crucial role in STEM education as it influences students' beliefs in their ability to succeed in STEM subjects and pursue STEM-related careers. Halim et al. (2021) highlight that the underrepresentation of women and racial minorities in STEM fields demonstrates the need for greater encouragement and support for these groups to pursue STEM-related educational and career goals. Self-efficacy plays a crucial role in STEM education, particularly in influencing students' interest, engagement, and career aspirations in STEM fields. According to Falco and Summers (2017), they also discuss the importance of self-efficacy in the context of STEM education by emphasizing how it relates to the engagement and persistence of female and other underrepresented students in the STEM education to career pipeline.

Specifically, they determined that an individual's confidence in their ability to succeed in a specific area, what they define as self-efficacy, is crucial in shaping their commitment to and sustained engagement in STEM fields. They note that the anticipated outcomes of taking courses necessary for STEM careers are closely linked to students' self-efficacy beliefs in math and science. Further, they argue that students will only act on career interests to the extent that they believe they can perform the required tasks in a given occupation without perceiving overwhelming obstacles to their success.

2.4 STEM EDUCATION AS A TOOL FOR ENVIRONMENTAL ENGINEERING

STEM education lays the groundwork for developing the next generation of engineers across disciplines, collectively working towards innovative environmental solutions. It is crucial for realizing tangible achievements in environmental engineering and student's heightened engagement in project-based learning. For example, Kang et al. (2012) describe a project-based learning initiative where high school students, simulating the roles of professionals, investigated and formulated solutions for contaminant sources in drinking water in a fictional town named "Hydroville". This method aimed to enrich students' understanding of water quality issues through a problem-based learning framework, where they actively engaged in data collection, analysis, and solution formulation, enhancing their scientific inquiry skills for addressing real-world environmental challenges.

A comparative study involving a second group of students using an alternate traditional curriculum revealed compelling outcomes: 72% of students engaged with the "Hydroville" curriculum successfully formulated at least one active inquiry question, markedly higher than the 52% achievement rate among those with the alternative curriculum. Furthermore, after completing the "Hydroville" curriculum, 44% of students proposed at least one hypothesis-driven approach.

This is a significant increase from an initial 13%, underscoring the effectiveness of immersive, problem-based STEM education in fostering critical thinking and problem-solving abilities. By incorporating local knowledge and practices, these STEM projects ensure that solutions are not only technically viable but also socially accepted and sustainable.

Al-Balushi & Al-Aamri (2014) also conducted a similar study with 11th-grade female students, implementing environmental science projects to boost their environmental knowledge and attitudes towards science. The experimental group tackled five diverse environmental projects over two months, contrasting with the control group's traditional education approach. These projects included creating a documentary on nature reserves, initiating a recycling campaign, compiling a report on global warming's impact, organizing an exhibit on food security, and performing a play about the red tide phenomenon. Through collaborative efforts, research, and creative output, such as documentaries, campaigns, and exhibits, the projects aimed to enrich students' understanding of environmental science and foster a positive science disposition.

Students were then tested using an Environmental Knowledge Test (EKT) and Science Attitude Survey (SAS) developed by the researchers. The development of both tests incorporated critical feedback from an interdisciplinary team comprising of university faculty, science education supervisors, and an experienced high school science educator. This collaborative review process facilitated the refinement and alignment of test items with the educational objectives, ensuring their pedagogical validity and relevance. Furthermore, a preliminary validation phase engaged a cohort of students to evaluate the clarity, accessibility, and academic integrity of the test content. This step was beneficial in fine-tuning the instruments to accurately assess the targeted educational outcomes within the experimental framework of the study.

The findings of this study demonstrate the remarkable value of incorporating hands-on, relevant project-based learning into the engineering education framework. Such an approach not only enriches students' understanding of environmental challenges but also cultivates critical engineering skills, including analytical thinking, creativity, and the application of technical knowledge to real-world problems. This type of research highlights the effectiveness of interdisciplinary projects in enhancing environmental knowledge and fostering a positive attitude towards science and engineering among students, suggesting a paradigm shift towards more experiential learning methods in engineering education.

Furthermore, the study by Al-Balushi & Al-Aamri demonstrates significant improvements in students' environmental knowledge and attitudes towards science. This advocates for a more integrated and application-focused curriculum that prepares students for the multifaceted challenges they will face in their professional careers.

2.5 Community Empowerment through STEM Education for Engineering Solutions

Empowering communities through STEM education is a transformative approach that bridges the gap between engineering solutions and societal needs. By bringing together diverse fields of engineering in a collaborative effort to solve environmental challenges, these programs demonstrate the power of interdisciplinary cooperation. As evidenced in the following research studies and case studies profiled through such collaboration, engineers are not only able to apply their technical skills but also engage with and contribute to the communities they serve and make an impact on a new era of engineers.

Therefore, the U.S. government committed to enhancing STEM education and was significantly emphasized when it launched strategic initiatives and partnerships aimed at bolstering

STEM programs across the nation. According to (Kolbe & Rice, 2012), the Race to the Top (RTT) grant program was a federal competitive grant initiative whose primary goal was to incentivize and reward states for making significant education reforms aligned with federal priorities. The program aimed to drive innovation and improvement in K-12 education by encouraging states to implement ambitious reforms that would enhance student learning, improve educational outcomes, and close achievement gaps. States applying for this funding were asked to address STEM education throughout their grant applications.

In total, 19 states were awarded $4 billion. Although Texas did not apply for this grant, many states that did apply but did not win were motivated to review and adjust their educational policies to align with the competition's emphasis on STEM. This led to an overall increase in attention to STEM education nationwide, with many states seeking alternative funding sources, partnering with private organizations, or reallocating state funds to support their STEM initiatives. The Race to the Top program, therefore, had a catalytic effect, encouraging a broader movement towards improving STEM education across the country, beyond just the grant recipient states.

2.5.1 Strategies and Programs Leveraging STEM for Community Empowerment

Avendaño et al. (2019) investigated a pioneering initiative aimed at leveraging STEM education as a driving force for community empowerment through targeted engineering projects. This initiative is built on the foundation of strategic collaborations between school districts and higher education institutions, creating a synergy that addresses local challenges effectively. At the heart of this initiative is the STEM Lab School concept, which immerses students in engineering projects directly relevant to their communities. Avendaño et al. (2019), further observed that this experiential learning not only equips students with essential engineering skills but also plays a

significant role in addressing community needs, thereby promoting local well-being and sustainability.

The inclusion of community-centric engineering projects within the STEM curriculum is designed to engage students deeply in practical problem-solving that benefits their communities, bridging the gap between academic learning and societal contribution.

Moreover, Avendaño et al. (2019) found that this program provides undergraduate students with hands-on engineering experience, meaningful community participation, with the potential for careers in the STEM fields. The STEM Lab School fosters community engagement by offering access to specialized fabrication equipment, enhancing local STEM literacy. It introduces undergraduates to paid internships, allowing them to work directly with this equipment, which could spark their interest in pursuing engineering professions. Reflecting on the pronounced need for academic and financial support in underrepresented communities, Avendaño et al. (2019) emphasize that internship opportunities are crucial for nurturing the next generation of engineers and are integral to sustaining the STEM education pipeline.

Another example provided by Luecke et al. (2023) is the QBio-EDGE (Quantitative Biology-Empowering Diversity and Growth in Education) initiative, spearheaded by researchers at UCLA. This initiative is dedicated to advancing STEM education accessibility for students from communities traditionally marginalized in STEM paths of academia. The program's strategy centers on introducing students to the realm of scientific research and showcasing a spectrum of scientist role models. This approach aims to illuminate the practical implications of research competencies and cultivate sustainable connections with participating educational institutions. Luecke et al. (2023) say the initiative is tailored to uplift students from underprivileged backgrounds, motivating them towards STEM disciplines.

Additionally, Zhang & Perkins' (2022) research explores the significance of community engagement within the realms of community-centered education and empowerment. It highlights its critical role in fostering active participation across individual, organizational, and societal tiers. This engagement is portrayed as essential for tackling societal challenges, advancing educational outcomes, and improving residents' quality of life. The authors review the contributions of community schools, local organizations, and collaborative networks in promoting citizen involvement, establishing partnerships, and facilitating communal problem-solving efforts. Moreover, they outline the beneficial impacts of such engagement, including heightened social unity, a strengthened sense of democracy, and increased empowerment among community members, illustrating its pivotal role in creating a more informed, cohesive, and proactive society.

2.5.2 Impact of Community Engagement in Engineering Projects

The role of community engagement in engineering projects cannot be overstated, especially when it comes to enhancing environmental awareness and fostering the development of sustainable solutions. Research by Jin et al. (2019), highlights the pivotal role of collaborative efforts between educational institutions and local communities. They state this is particularly evident through partnerships like those with the Rio Bosque Wetlands Park, enriching the educational journey of students in environmental science programs. Such collaborations offer students hands-on, community-engaged research opportunities, enhancing academic experiences while simultaneously contributing to environmental conservation efforts.

Additionally, the study highlights the critical importance of mentorship in bolstering the success of students, especially those from underrepresented demographics, within STEM disciplines. Jin et al. highlight that effective mentorship, encompassing both formal and informal

relationships, is instrumental in nurturing students' cognitive growth, fostering their identification with scientific roles, and enhancing their technical and professional competencies.

Charleston's (2012) research further concludes that mentors are pivotal in offering support, motivation, and direction to minority students within the realm of STEM fields, including computer sciences. They aid these students in overcoming challenges and seizing opportunities in this field. Their research further emphasizes the importance of industry leaders engaging in collaborative partnerships with K-12 schools in economically disadvantaged areas to extend internship opportunities to underrepresented groups.

Another research conducted by Su & Jagninski's (2013), explores the significance of integrating community partnerships and engagement within engineering projects, particularly those involving marginalized youth. Their research highlights the following key points:

1. Integrating Experiential Learning with Engineering Practice: Su & Jagninski discuss the critical role of community partnerships; these collaborations leverage local knowledge and lived experiences, enriching students' understanding of engineering solutions' real-world implications and fostering a sense of ownership and commitment to community well-being.
2. Fostering Empowered Deliberative Engineering Solutions: Su & Jagninski's study highlights how community engagement provides a platform for students to apply their technical knowledge in meaningful ways, thereby empowering them to present innovative solutions to external stakeholders. It further elaborates that through such engagements, students gain the support necessary to enact tangible changes in local infrastructure projects. This demonstrates the practical application of their engineering skills, as detailed in the findings of Su & Jagninski.

3. Encouraging Youth Involvement in Engineering Decision-Making: Emphasizing youth participation in decision-making processes, Su & Jagninski advocate for engineering education programs to partner with organizations that elevate youth voices in community development. The engineering students contribute directly to discussions on local infrastructure improvements and urban planning, enhancing their civic responsibility and professional growth.
4. Sustainability and Civic Capacity in Engineering Education: The research addressed the sustainability of community-engaged engineering projects and the role of educational institutions in building civic capacity among young engineers. Investigating how partnerships can sustain long-term community benefits and foster students' abilities to develop policy and technical solutions at the local level is highlighted as essential.

In essence, Su & Jagninski's (2013) research explains the profound impact of community engagement and partnerships in engineering education, particularly for projects aimed at empowering marginalized youth. By fostering collaboration, experiential learning, and active participation in community development, these initiatives enhance the educational experience for engineering students and contribute significantly to local and broader societal advancements.

In 2013, a 5-year STEM strategic plan was released from the Committee on STEM Education National Science and Technology Council (Federal Science, Technology, Engineering, and Mathematics (STEM) Education Strategic Plan, 2013). It included 100Kin10 Partnership which was a national initiative launched in response to the call to prepare 100,000 excellent STEM teachers over a decade. The partnership comprises a network of organizations, including foundations, nonprofits, government agencies, and academic institutions across the country, working together to achieve this goal. The private sector was called to engage with their

communities in an effort to promote the STEM field. Therefore, a collaboration between the Texas Instruments (TI) Foundation and Educate Texas to create a STEM District in Lancaster ISD reflected a local initiative that originated from the broader national emphasis on encouraging private sector involvement in STEM education. Additionally, community engagement was also highly encouraged. The focus on community engagement and the hosting of events like science fairs and robotics competitions were inspired by the broader national emphasis on STEM education. This includes efforts by the federal government to promote STEM education through initiatives and programs that encourage local communities, businesses, and educational institutions to collaborate in support of STEM learning.

2.6 Gaps in Research

Holistic Interdisciplinary Approach: Existing research lacks a comprehensive examination of holistic, interdisciplinary strategies integrating STEM education with environmental engineering to achieve social sustainability and empower underserved communities. A gap exists in research aimed at supporting community empowerment through STEM education, particularly tailored to the unique needs of economically underserved Hispanic communities.

Community Partnerships and Engagement: There's a notable gap in detailed case studies on the effect of community partnerships on educational outcomes and community development, particularly concerning empowering marginalized youth through engineering projects. Despite recognizing mentorship's critical role, detailed studies on implementing and scaling mentorship structures to support underrepresented students in STEM are scarce.

Underrepresentation of Minorities in STEM Fields: There's a significant gap regarding the representation of minorities, particularly in Hispanic communities, within STEM disciplines.

Research to date has not sufficiently explored interdisciplinary strategies to close this STEM gap for underrepresented groups.

Culturally Attuned STEM Education: There is a scarcity of studies on the importance of culturally attuned parental engagement in STEM, indicating a gap in understanding how integrating cultural values and community needs can promote STEM participation and success.

Barriers to Equitable STEM Opportunities: Identified barriers include socio-economic constraints, gender stereotypes, and insufficient access to quality STEM resources and support systems, suggesting a need for research on strategies to overcome these barriers in an effort to foster equity and empowerment within STEM.

2.7 CONCLUSION

In conclusion, the integration of STEM education presents a compelling avenue for addressing the dual goals of community empowerment and social sustainability. The examples and studies reviewed herein not only validate the critical role of STEM education in fostering a problem-solving mindset but also demonstrate its capacity to produce tangible, quantifiable benefits for communities. Building upon the foundational research of pioneers in the field, this review emphasizes the need for future investigations to further explore the impact of an interdisciplinary approach to implementing STEM education that results in improved student pursuits in STEM fields. This research is crucial for validating the significance of STEM educational initiatives in fostering the creation of sustainable engineering solutions. It highlights the transformative capacity of STEM education in equipping students with the essential engineering skills required for future challenges.

Furthermore, it's imperative to acknowledge and take steps towards dismantling barriers contributing to the underrepresentation of minorities in STEM, especially within Hispanic

communities, in order to build a resilient and diverse engineering workforce. The notable gap in representation exacerbates the disconnect between these communities and the STEM fields, significantly constraining students' interest, self-efficacy, and aspirations towards STEM careers. This lack of diversity not only challenges the empowerment of these communities but also directly affects the capacity of environmental engineering initiatives to achieve their goals of social sustainability.

To advance equity in STEM education, it's crucial to acknowledge that overcoming these barriers is a collective responsibility, not solely that of STEM educators. Accordingly, we will examine a recommended interdisciplinary framework in detail, focusing on the various steps under each component as a range of adaptable strategies within STEM education. This approach demonstrates that while the components themselves are essential, the specific steps within each can be selectively implemented by STEM educators, depending on available resources, allowing for a starting point that aligns with their capabilities. Initiating this process requires taking a first step, understanding that subsequent efforts are part of a continued and consistent journey, rather than a quick fix.

Chapter 3: Interdisciplinary Framework

3.1 Introduction

This chapter expands upon the detailed literature review presented in Chapter 2, highlighting the transformative power of utilizing STEM education as a tool to enhance the environmental engineering notions of social sustainability and community empowerment. It introduces an interdisciplinary framework designed to achieve these goals, providing a structured approach for implementation.

This interdisciplinary framework will be referred to as E3. The **E**co-Engineering **E**ducation for **E**mpowerment (E3 Framework) skillfully incorporates the notion of "Eco," referring to ecological or environmental concerns, with "Engineering Education" to emphasize the integration of environmental engineering principles into educational practices. The term "Empowerment" highlights the framework's goal of supporting individuals and communities to take meaningful actions toward sustainability and environmental stewardship.

3.2 E3 Framework Component Overview

The interdisciplinary framework is structured around three core components:

1. Instruction-Initiated Resource Activation (I^2RA): This component lays the groundwork for improving STEM education by identifying essential resources to establish clear program goals and objectives. The emphasis here is on the "activation" or mobilization of STEM resources that are already available within the community, including physical assets, institutional partnerships, and any existing educational programs.
2. Culturally Attuned Parent Engagement: This element emphasizes engaging Hispanic parents in their children's STEM education through culturally responsive practices, bridging educational experiences from school to home.

3. Community-Centered STEM Education: This aspect focuses on integrating local environmental challenges and solutions into the STEM curriculum, fostering education that is deeply rooted in the community's context and needs. Furthermore, by leveraging partnerships with community organizations, businesses, and higher education institutions the potential for job shadowing and mentorship opportunities exist.

3.3 Direct Connections: From Literature to Framework Components

An examination of literature themes compared to the interdisciplinary framework components reveals a mutual relationship where theoretical insights inform practical strategies. For instance, the discussion on Social Cognitive Theory within engineering education highlights the importance of self-efficacy, directly informing the I^2RA component by advocating for resource activation that enhances students' confidence in their STEM capabilities. Similarly, insights into community-centered approaches and constructivism in engineering emphasize the necessity of Culturally Attuned Parent Engagement and Community-Centered STEM Education.

3.4 Bridging Theory and Practice: Enhancing STEM Education through an Interdisciplinary Framework

The critical examination of STEM education's role within environmental engineering, as presented in the literature review, demonstrates its potential to drive significant advancements in social sustainability and community empowerment. Reflecting on the theoretical foundations and observed findings, a proposed interdisciplinary framework composed of Instruction-Initiated Resource Activation (I^2RA), Culturally Attuned Parent Engagement, and Community-Centered STEM Education is presented. This framework aims to address the identified gaps and leverage opportunities to enhance STEM education's impact on environmental engineering solutions.

3.4.1 Diagram of the E3 Interdisciplinary Framework

Figure 3.1: E3 Interdisciplinary Framework depicting the interconnected elements

3.5 CONCLUSION

This chapter outlines a comprehensive plan for implementing an interdisciplinary framework that bridges theoretical insights with practical applications in STEM education. By integrating the latest research, utilizing mixed methodological approaches, and fostering extensive stakeholder engagement, this framework is positioned to significantly enhance STEM education and advance the goals of environmental engineering toward social sustainability and community empowerment. Chapter 8 will further investigate into detailed case studies, such as "Engage to Empower," further illustrating the framework's impact and potential.

Chapter 4: How-to Guide: Instruction-Initiated Resource Activation (I^2RA)

4.1 Introduction

This chapter outlines the Instruction-Initiated Resource Activation (I^2RA) component of the interdisciplinary framework which is a strategic method tailored at bolstering STEM education in underserved communities. I^2RA focuses on the proactive identification, adaptation, and deployment of educational and community STEM related resources to empower these communities. Recognizing the challenges often faced in underrepresented areas, this method is flexible, acknowledging that the work may begin with just one or two dedicated educators. These individuals play a pivotal role, using their deep understanding of student needs and community dynamics to initiate the STEM program, often without extensive institutional support.

While the ideal scenario includes forming a STEM Advisory Board to foster a collaborative environment and broaden stakeholder engagement, this guide emphasizes that such a structure, though beneficial, is not a prerequisite for success. In many instances, educators operate with limited support, making it essential to adapt the I^2RA process to fit their unique circumstances. Even a small team of educators can drive significant change by leveraging their knowledge and networks within the community.

This guide proposes starting with what is feasible, whether that means working closely with a handful of committed individuals or aiming to establish a more formalized STEM Action Committee or Advisory Board as resources and support permit. This ensures that this STEM initiative remains adaptable, scalable, and deeply connected to the community it serves. The ultimate goal is to create a sustainable, quality-focused STEM education program by harnessing local resources, filling gaps, and expanding efforts as opportunities arise. This iterative and adaptable approach ensures that even in STEM resource-constrained environments, passionate

educators can make a profound impact, reflecting the resilience and collaborative spirit of the communities they serve.

4.2 STEP-BY-STEP I²RA GUIDE

The Instruction-Initiated Resource Activation (I^2RA) component represents a focused strategy for the efficient collecting of internal and external resources within the educational community. This approach is designed to significantly enhance the outcomes of STEM education by leveraging innovative teaching methods, partnerships, and supplies. The following guide outlines the key steps to successfully implement the I^2RA approach.

The process of identifying goals and objectives in the Instruction-Initiated Resource Activation (I^2RA) framework is pivotal in aligning educational initiatives with the specific needs of the community. Therefore, the first step serves as the foundation upon which all subsequent activities are built, ensuring that efforts are targeted, effective, and capable of achieving the desired impact on STEM education.

4.2.1 Step 1: Identify Goals and Objectives

In areas where resources are limited, often one or two educators spearhead the initiation process by meticulously assessing the specific challenges and needs within the STEM educational landscape. This foundational step can involve conducting targeted surveys, direct observations, and organizing meetings with key stakeholders such as students, parents, other teachers, or local community STEM partners. This approach ensures that even in the absence of a broader STEM Advisory Board, essential feedback is gathered to inform the program's direction.

After gathering this crucial input, these educators or small teams then engage into a deeper analysis of the feedback. By leveraging the insights gained, they aim to thoroughly understand the

community's unique needs and challenges. Such detailed evaluation is vital for identifying areas requiring immediate attention and action.

Equipped with this in-depth analysis, even a limited number of dedicated individuals can effectively outline clear and achievable goals for STEM education enhancement. Beginning with a manageable set of goals allows for focused efforts and gradual, meaningful expansion over time. This strategy accommodates sustainable growth and continuous improvement, ensuring the STEM program remains responsive to the community's evolving needs, even without the formal structure of a STEM advisory board. This tailored approach promotes adaptability and resourcefulness, meeting passionate educators where they are and facilitating impactful STEM education initiatives in underserved settings.

4.2.2 Step 2: Engage Stakeholders and Assess Resources

A critical initial action in the I^2RA process is the thorough inventory of the school's available resources. This inventory spans physical assets such as technology and facilities to indirect assets such as expertise and community relationships. The aim is to paint a comprehensive picture of available resources, identifying gaps and opportunities for improvement. This step moves beyond mere cataloging to assess the condition and relevance of these resources for modern STEM education.

The subsequent analysis of available resources seeks to identify strengths, weaknesses, and gaps. This process should consider into how effectively these resources are currently utilized and how they could be better leveraged to enhance STEM education. Such insights might reveal areas of excellence to build upon or critical needs for modernization as well as goals leading to strategic community centered STEM engagement.

Finally, this stakeholder engagement should begin practically, often with a small core group, and then expand as the STEM program evolves. This phase is crucial, ensuring diverse perspectives in decision-making and STEM resource allocation. Including views from teachers, administrators, parents, and local businesses across the school and community ensures a holistic approach to STEM education enhancement. This fosters a collaborative environment even within constrained settings.

4.2.3 Step 3: Develop an I^2RA Plan

Create a detailed plan. The development of a comprehensive I^2RA plan involves outlining steps to activate and utilize resources efficiently. This plan serves as a roadmap, detailing the harnessing of each identified STEM resource to achieve the set goals, including specific tasks, responsibilities, timelines, and expected outcomes. This structured, yet flexible approach, allows for adjustments based on feedback and evolving circumstances, guiding all STEM stakeholders through the process of resource activation.

Assigning roles and responsibilities for each goal ensures the smooth execution of the plan. Clear communication and an understanding of each stakeholder's strengths facilitate effective collaboration. For example, a technology-savvy teacher might lead digital resource integration, while an administrator focuses on logistics and partnerships. This outline ensures accountability and helps track the progress of initiatives, crucial for the plan's success.

A well-crafted I^2RA plan acts as a guiding example for stakeholders, ensuring that each action taken aligns with broader STEM educational goals. It's about creating a collective vision for STEM enhancement, where every stakeholder knows their role and how to contribute effectively. This collaborative approach is essential for the plan's implementation, driving the initiative towards achieving its objectives and enhancing STEM education within the community.

4.2.4 Step 4: Resource Mapping and Protocols Establishment

Resource mapping in the I^2RA process involves a strategic categorization and planning for the use of various STEM resources. It's about understanding how different resources, human, physical, and financial, can best serve the STEM educational objectives. This step ensures the effective arrangement of all STEM resources, maximizing benefits for STEM students and eliminating redundancies in resource utilization.

Strategic utilization of resources requires careful planning and coordination. It involves aligning the mapped resources with the specific needs and goals identified in the I^2RA plan. This could mean scheduling resources for maximum accessibility, coordinating human resources to meet curriculum needs, and allocating financial resources with a focus on sustainability. Ongoing management and adjustment ensure that resources support STEM educational goals effectively and efficiently.

Therefore, establishing clear protocols for requesting and allocating resources is important. This process allows for a systematic approach to resource management, ensuring requests align with STEM educational goals and available resources. Transparent and equitable protocols ensure fair access to STEM resources for all stakeholders, playing a vital role in maintaining order and efficiency in resource allocation and contributing to the overall success of the STEM program.

4.2.5 Step 5: Raise Awareness and Communicate Benefits

Effective communication of the I^2RA initiative's benefits is essential for securing ongoing support and participation. Regular updates, STEM success stories, and evidence of program progress are vital in keeping the community engaged and supportive. Highlighting the positive impacts of the I^2RA approach through various channels reinforces the value of the initiatives and fosters a sense of collective achievement within the community.

Promoting a culture of resource sharing and collaboration supports the initiative's success. Encouraging stakeholders to view STEM resources, knowledge, skills, time, materials, as communal assets for the collective benefit enhances the STEM educational experience and strengthens community bonds. Activities and events that highlight this collaborative culture can significantly impact fostering a supportive STEM educational environment.

The key to raising awareness and communicating these benefits lies in the clarity, frequency, and accessibility of the messages. Utilizing diverse channels to reach all STEM community members ensures that the information is disseminated widely, building a shared vision and a strong foundation for the initiative's continued success and community engagement.

4.2.6 Step 6: Implement, Monitor, and Adjust

The implementation phase brings the I^2RA plan to life, translating theoretical strategies into practical STEM educational enhancements. Effective implementation hinges on coordinated efforts, adherence to timelines, and the active involvement of all stakeholders. Continuous monitoring during this stage tracks the progress of each initiative, identifying any issues or barriers, and facilitates necessary adjustments to keep the plan on track and effective.

Monitoring progress involves not just tracking the implementation of initiatives but also assessing their impact on STEM educational outcomes. This requires a mix of quantitative and qualitative measures to evaluate success and identify areas for adjustment. Being responsive to this data and willing to adapt the plan as necessary, ensures the initiatives remain aligned with STEM educational goals and community needs.

The cycle of implementation, monitoring, and adjustment is ongoing, reflecting the dynamic nature of STEM educational needs and resource availability. This phase emphasizes the importance of flexibility and responsiveness, ensuring the STEM program continually evolves and

improves in response to feedback and changing circumstances, maintaining its relevance and impact.

4.2.7 Step 7: Evaluate and Reflect

Evaluation and reflection are critical for understanding the I^2RA initiatives' broader impact on the STEM educational landscape. This step goes beyond monitoring to assess the effectiveness of actions taken and their contribution to long-term sustainable goals. Comprehensive evaluations consider various factors such as student engagement, STEM academic achievement, or teacher and community satisfaction for providing insights into the initiative's overall success and areas for improvement.

Reflection is a crucial component of this process, offering a chance to consider lessons learned, successes achieved, and challenges faced. It's an opportunity to integrate these insights into future planning, ensuring the continuous improvement of STEM education initiatives. Recognizing and celebrating STEM achievements during this phase motivates continued effort and supports a culture of innovation and progress.

Regular evaluation and reflection reinforce the initiative's goals, highlight the value of the work being done, and ensure that efforts remain aligned with the community's evolving needs. This step fosters a culture of continuous learning and improvement, crucial for sustaining the initiative's momentum and ensuring its long-term success.

4.2.8 Step 8: Share Success Stories

Sharing the successes of the I^2RA initiative serves multiple purposes: it demonstrates the positive changes brought about by the STEM program, inspires others to contribute, and attracts additional support and resources. Success stories, whether big or small, provide tangible evidence

of the initiative's impact, helping to build a positive narrative around the school and its commitment to innovative STEM education.

Celebrating these successes fosters a sense of pride and accomplishment among students, teachers, and the community. It highlights the collaborative effort required to achieve these STEM outcomes and encourages ongoing support and engagement from all stakeholders. By publicizing these STEM achievements through various channels, the initiative strengthens its visibility and credibility, drawing in more resources and partnerships.

Success stories are not just about STEM recognition but also about reinforcing the collaborative, resourceful nature that underlines the initiative. They serve as an inspiration for potential collaborators and funders, showcasing the initiative's effectiveness and the meaningful impact of collective efforts on enhancing STEM education in underserved communities.

4.2.9 Step 9: Plan for Sustainability and Expansion:

Ensuring the sustainability and potential expansion of the I^2RA initiative is crucial for its long-term impact. This step involves strategic planning to maintain and grow the initiative, leveraging successful strategies and exploring opportunities to extend its reach. Sustainability planning considers resource management, stakeholder engagement, and continuous evaluation to ensure the initiative remains viable and impactful.

Expansion planning looks at how the initiative's successes can be replicated or scaled up, potentially benefiting a broader STEM audience. This might involve adapting successful programs for different contexts, securing additional funding, or fostering partnerships with other schools or communities with respect to STEM education. A focus on scalability and adaptability ensures that the initiative can grow in response to new opportunities and challenges. Sustainability and expansion are about building on the successes of the initiative, ensuring its benefits continue to

reach and positively impact the community. Strategic planning in these areas ensures that the initiative remains a dynamic and evolving force for enhancing STEM education.

4.2.10 Step 10: Continuous Improvement:

The principle of continuous improvement is central to the I^2RA approach. It involves regularly reviewing and updating the I^2RA plan based on feedback, outcomes, and evolving educational STEM needs. This step is about being adaptable and responsive, ensuring that the STEM educational strategies remain relevant and effective. Continuous improvement requires a proactive stance, seeking out new opportunities for resource activation, and being open to change. It involves keeping abreast of the latest developments in education and technology, as well as the changing needs of students and the community. This process might involve regular review meetings, surveys to gather feedback, and ongoing research into new educational trends and resources. By continuously refining the I^2RA plan, educators can ensure that it stays aligned with the goal of providing the best possible education to students.

Adapting to new challenges and seizing opportunities for resource activation are also key aspects of continuous improvement. This requires a flexible mindset and a willingness to experiment with new ideas. It might involve piloting new programs, exploring partnerships with emerging industries, or integrating new technological tools into the curriculum. Continuous improvement is not just about solving problems; it's about constantly pushing the boundaries of what is possible in education. By embracing this principle, educators can establish a dynamic and innovative learning environment that aligns with the initial goals set forth. This approach not only caters to the current needs of students but also strategically prepares them for future challenges, reinforcing the importance of partnerships with companies as suggested at the outset. In recognizing the paramount importance of continuous improvement, it becomes evident that the

foundation for such advancement lies in the I^{2}RA component's primary goal; Engage Stakeholders. By incorporating innovative strategies, educators not only propel the STEM educational landscape forward but also reinforce the collaborative framework essential for community development. This connection between educational evolution and stakeholder engagement demonstrates the necessity of a united approach, where each stride towards innovation is mirrored by a step closer to a more involved, transparent, and mutually beneficial partnership with the community.

4.3 CONCLUSION:

Instruction-Initiated Resource Activation (I^{2}RA) is more than just a component; it's a transformative strategy that empowers educators to significantly enhance STEM educational outcomes. By systematically implementing the steps of I^{2}RA, STEM educators not only help bridge resource gaps but also cultivate a rich, resourceful learning environment. This environment is conducive to both student and teacher growth, fostering a community where STEM education is not just about imparting knowledge but about creating a vibrant, interactive, and supportive learning culture.

The core of I^{2}RA lies in its ability to foster a culture of collaboration and resource sharing. When educators, community members, and industry partners come together, the possibilities for enriching the STEM educational STEM experience multiplies. This collaboration leads to an improved STEM education, where students gain from diverse perspectives and real-world experiences. Such a culture not only benefits the students but also motivates the educators and community members, creating a sense of shared purpose and achievement.

The implementation of I^{2}RA goes beyond the immediate classroom benefits. It sets the foundation for a long-lasting positive impact within the community. By involving local STEM businesses, industry experts, and community leaders, I^{2}RA creates a bridge between the school

and the community, ensuring that STEM educational initiatives are relevant, practical, and beneficial to local needs. This relevance is crucial in ensuring that STEM education is not in a vacuum but is a vital part of community growth and development.

As the STEM educational landscape changes, so must the strategies employed by educators. I^2RA is not a static plan; it is designed to evolve and adapt. Continuous feedback, regular assessment, and an openness to change are integral parts of I^2RA. This flexibility ensures that the approach stays relevant and effective, aligning with the changing STEM educational needs and community dynamics.

In conclusion, Instruction-Initiated Resource Activation is more than a strategic plan; it is a call to action for STEM educators, community members, and industry partners. It is an invitation to collaboratively contribute to a sustainable, dynamic, and inclusive STEM educational environment. By incorporating I^2RA, we take a significant step towards not just educating a generation but empowering a community to thrive in an interconnected and ever-changing world. Building on this momentum, attention now shifts our focus to the equally crucial component of enhancing parent engagement. This step in essential for developing a supportive and accessible STEM educational landscape for underserved communities.

Chapter 5: How-to Guide: Culturally Attuned Parent Engagement

5.1 Introduction

In this dissertation, Culturally Attuned Parent Engagement (CAPE) in STEM Education is defined as a purposeful and welcoming strategy carried out by STEM educators and community stakeholders. The main objective of CAPE is to make STEM education accessible and captivating for all children through empowering their parents and guardians by tailoring strategies to meet the specific logistical and support related challenges of the underserved community. This supportive and adaptable approach aims to bridge the gap between underserved communities and STEM education, thereby creating environments where every child has the opportunity to explore, learn, and excel in STEM fields. By directly assisting parents and guardians, the success and support of students are significantly enhanced. Such a strategy not only elevates STEM educational outcomes but also nurtures a culture of engagement, collaboration, and empowerment across diverse communities.

5.2 Step-By-Step Parent Resource Engagement Program (PREP) Guide

Specifically, this research focuses on the West Texas counties of El Paso and Presidio, as detailed in Chapter 1.2. The findings indicate that the customary culture within these counties is characterized by working-class Hispanic parents, who primarily speak Spanish and often lack formal higher educational experiences. This demographic plays a pivotal role in supporting their children's journey in STEM education, underscoring the importance of culturally attuned engagement strategies. Therefore, this approach is carefully designed to align with the specific realities and daily challenges these disadvantaged families encounter. By focusing on clear communication, practical support systems, and valuing each parents' involvement, the strategy seeks to foster an environment where every parent feels equipped and confident to support their

child's interest and achievements in STEM fields. The objective is to ensure that parental support systems are straightforward, acknowledging the pivotal role of parents in nurturing their children's potential and aspirations in STEM, without relying on specialized terminology or preconceived notions of family engagement.

Implementing this component, makes the STEM program not only accessible but also dynamic and responsive to the specific needs of the community it serves. The application of the following steps aims to strengthen the connection between STEM education and the particular needs and realities of working-class Hispanic families, making STEM fields more accessible and appealing to a broader audience. The steps for CAPE are broadly applicable and involve focusing on the core principles of engagement, communication, and practical support, all tailored to the realities of working-class families in underserved areas. Importantly, these steps are designed to be implemented progressively, allowing for flexibility in execution. This phased approach caters to the unique conditions of underrepresented areas, where initial efforts may begin with the dedication of a few educators. Their central understanding of the local community and student needs lays the foundation for the approach, affirming that beginning with even a single step is a significant and valuable start to incorporating probably the single most important factor of most Hispanic households; the paramount importance of family influence.

5.2.1 Step 1: Enhance Parental Support in STEM Initiatives

The first step in the Culturally Attuned Parent Engagement (CAPE) initiative focuses on enhancing parental support in STEM initiatives. This involves providing parents with resources that make STEM concepts both understandable and relevant, connecting these ideas to real-life applications. The goal is to demystify STEM for parents, thereby making the field not only more accessible but also showcasing its practical value in daily life and future career paths. This

connection is crucial for working-class Hispanic families in West Texas, where educational resources may be limited, but the aspiration to support their children's academic and professional futures runs deep.

To achieve this, the strategy includes the integration of freely available online platforms and educational resources into the curriculum. These digital tools offer a wide range of engaging STEM content, from interactive lessons to experimental projects and even free STEM challenges, without imposing additional financial burdens on schools or families. By harnessing the power of the internet, STEM education becomes boundless, enabling parents and children to explore, learn, and grow together. Moreover, the creation of simple, home-based STEM projects encourages hands-on learning. These projects, designed with everyday materials, can be particularly engaging during extended school breaks, providing families with meaningful activities that reinforce STEM learning outside the classroom.

Recognizing the central role of family in Hispanic culture, this step is designed to strengthen the bond between parents and their children through shared educational pursuits. It acknowledges that parents are pivotal in nurturing their children's interest in STEM, despite potential barriers such as language differences or lack of formal education. By equipping parents with the right tools and knowledge, CAPE aims to empower them to become active participants in their children's STEM education. This effort not only supports students' academic success but also reinforces the importance of family involvement, aligning with the values deeply rooted in the community.

5.2.2 Step 2: Establishing a Foundation for the Parent Resource Engagement Program (PREP)

The initiation of the Parent Resource Engagement Program (PREP) hinges on creating a small but effective team dedicated to enhancing culturally attuned parent engagement. Initially, this may begin with one or two pioneering educators who possess a deep understanding of the community's cultural dynamics and the specific challenges faced by working-class Hispanic families in STEM education. These educators serve as the cornerstone, laying the groundwork for what will eventually expand into a more comprehensive PREP team. Their immediate goal is to identify key areas where parent engagement can be most impactful, focusing on strategies that align with the cultural values and daily realities of the families they aim to serve.

As the program gains momentum and resources become available, the aim is to broaden the team to include administrators, community members, and potentially local industry professionals who share a commitment to fostering a culturally inclusive educational environment. This expanded team will leverage a diverse set of perspectives to develop and oversee a range of strategies aimed at deepening meaningful parent engagement. It's essential for the team's composition to reflect the cultural diversity of the school's community, ensuring a comprehensive understanding of the various cultural nuances and expectations. This diversity is not just a strength but a necessity, enabling the PREP team to create engagement strategies that are genuinely inclusive and resonate across different cultural groups within the school.

The operational phase focuses on the PREP team actively working to ensure that every strategy and initiative undertaken is culturally sensitive and tailored to the unique needs of the community it serves. This involves regular assessment and adaptation of engagement practices to ensure they remain effective and relevant. By mirroring the cultural makeup of the school

community, the PREP team is better positioned to identify and address potential barriers to engagement, crafting solutions that are both innovative and practical. The presence of diverse voices within the team not only enriches the program's approach but also sends a powerful message of inclusivity and respect for cultural diversity to the entire school community. Over time, the PREP team aims to establish a sustainable model of parent engagement that can evolve alongside the changing needs of the community, reinforcing the vital role of family influence in educational success.

5.2.3 Step 3: Assess Parents' Needs and Preferences

Conducting a comprehensive assessment of the parents' needs and preferences within the school community is a critical step in the PREP initiative. This assessment involves identifying the various cultural groups represented in the school, including understanding their languages, traditions, values, and customs. It may involve collecting data through surveys, interviews, or community meetings. Understanding the cultural landscape of the school is essential for developing tailored strategies for parent engagement. This assessment helps in identifying specific needs and preferences of different cultural groups, ensuring that the PREP initiatives are attuned and respectful of these differences.

Identifying the languages, traditions, and customs of the families involved helps in creating a more inclusive and welcoming environment for all parents. Understanding these cultural elements is crucial for effective communication and interaction with parents. For instance, knowing the languages spoken by parents can guide the school in providing translated materials and interpretation services. This step involves identifying the primary languages spoken in the student community and providing translations for newsletters, announcements, permission slips, and other important school communications. The goal is to eliminate language barriers that can

prevent parents from fully participating in their children's STEM education. Translation of materials is a practical way to show respect for the linguistic differences of the school community and to ensure that all parents have the opportunity to be informed and involved on the path to STEM education.

Ensuring accessibility of school information is not just about language translation but also about considering the cultural context in communication. This might mean adapting the content to be more culturally attuned or using communication channels that are more commonly used within certain cultural groups. For example, some communities may prefer digital communication, while others might value face-to-face interactions or printed materials. Understanding these preferences and adapting communication strategies accordingly is key to effective parent engagement.

Recognizing important cultural traditions and holidays can also assist in planning school events and activities that are inclusive and respectful of these cultural observances. This step is about valuing and incorporating the rich cultural diversity present in the school community into the fabric of the school's operations and interactions.

5.2.4 Step 4: Build Trust and Relationships through Open Communication

In the journey to enhance STEM education accessibility for underserved communities, establishing a foundation of trust with parents stands as a pivotal step within the Parent Resource Engagement Program (PREP). This effort starts with actively engaging in meaningful dialogues with parents, attentively listening to their concerns, aspirations, and feedback. Establishing such trust is contingent upon the consistency and sincerity of these interactions, which can be facilitated through varied communication platforms such as parent-teacher conferences, community forums, and informal meet-ups such as "Coffee with the Principal" on a Saturday morning. The essence of this step lies in fostering a welcoming an inclusive environment where every parent feels

acknowledged and respected, thus reinforcing their invaluable role within the STEM educational ecosystem.

The process of building trust extends beyond the simple transmission of information; it necessitates the creation of avenues for mutual communication, where parents' voices are not only heard but are integral to the dialogue. Schools are encouraged to set up platforms that respect and accommodate the cultural diversity of their community, allowing parents to share their insights and engage in discussions about STEM projects, student achievements, and more. Such efforts should be complemented by leveraging mobile communication methods such as messaging apps for regular updates and support, alongside offering resources like recorded tutorials and guides on the school's website. These measures ensure that all families remain connected and supported.

Moreover, scheduling engagement opportunities outside conventional hours through virtual meetings and workshops clearly demonstrates the program's commitment to adaptability and inclusiveness. By prioritizing flexible interactions, schools can better accommodate the busy schedules of working parents, thus removing barriers to participation. This holistic approach to communication is instrumental in creating a tight-knit community of STEM educators, parents, and students, where trust and mutual respect pave the way for collaborative efforts to enhance STEM learning outcomes. Through these concerted and thoughtful strategies, the PREP initiative aims to not just foster STEM educational success but to build lasting relationships that empower both students and their families.

5.2.5 Step 5: Offer "Welcoming" Workshops

Organizing workshops and training sessions that are culturally sensitive is an essential aspect of PREP. These workshops aim to help parents in underserved communities understand the educational system, including its expectations and opportunities for their children. The content and

delivery of these workshops should be tailored to address the unique challenges and needs of various cultural groups within the school community. This might involve workshops on navigating the school system for parents who are new to the country or sessions on specific educational topics that parents have expressed interest in. By making these workshops culturally attuned, schools demonstrate their commitment to inclusivity and respect for the diverse backgrounds of their students' families.

Ensuring that the workshops are culturally sensitive also means providing them in languages accessible to all parents. It's about creating a learning environment where all parents feel comfortable and engaged. This could involve using bilingual educators or interpreters, incorporating culturally attuned examples and case studies, and being mindful of cultural differences in communication and interaction. These workshops serve as a platform not only for STEM education but also for cultural exchange and mutual learning among parents and STEM educators.

5.2.6 Step 6: Enhancing Community Connection through a Student-led STEM Showcase

Hosting a student-led STEM Showcase emerges as a key strategy within the Parent Resource Engagement Program (PREP). This initiative serves as a dynamic platform for students to exhibit their STEM projects and achievements, directly involving parents and the broader community in their learning journey. Planning these STEM showcases on an annual or bi-annual basis not only fosters a culture of celebration and recognition of students' efforts but also significantly boosts interest and enthusiasm for STEM fields among students and their families.

The inclusion of interactive booths, hands-on activities, and family engagement exercises transforms the showcase into a communal learning experience, where the wonders of STEM are made tangible and accessible to all attendees. By inviting local STEM professionals and

organizations to participate, the event also facilitates valuable networking opportunities, allowing students and parents to interact with experts and enthusiasts in the field. Such interactions can demystify STEM careers, providing real-world context and inspiration for students' aspirations.

Moreover, integrating cultural elements and considerations into the planning and execution of these showcases ensures that the events resonate with the diverse backgrounds of the community. Highlighting projects that address local issues can also enhance the relevance and impact of the showcase, underscoring the importance of STEM solutions in everyday life and community wellbeing. This student-led STEM Showcase not only acts as a catalyst for sparking interest in STEM among underserved communities but also strengthens the bond between schools, families, and local entities. By centering the event around student achievements and fostering an environment of inclusivity and collaboration, the STEM showcase highlights the pivotal role of community engagement in driving forward the mission of accessible STEM education. Through such initiatives, the PREP seeks to not only celebrate the present achievements of its students but also to lay the groundwork for a future where every student sees the potential for a path in STEM, supported by their families and community at large.

5.2.7 Step 7: Local Guest Speakers in STEM Education

This step is achieved by inviting local STEM professionals, who are reflective of the community's own diversity, to speak about their journeys and successes in the STEM field. By sharing their personal experiences growing up and the challenges they overcame, these guest speakers serve as tangible examples of achievable STEM careers for individuals from similar backgrounds. This initiative aims to inspire parents by providing practical advice on how they can effectively support and encourage their children's interests and pursuits in STEM, emphasizing the importance of parental involvement and cultural understanding in fostering a conducive

environment for STEM education. Such engagements not only enrich the STEM educational experience but also illuminate the myriad of career pathways within STEM fields, making these STEM careers more tangible and attainable for students and their families.

5.2.8 Step 8: Invite Parents to PREP Meetings and Solicit their Valuable Input

Inviting parents to PREP meetings and actively seeking their input emerges as a vital strategy. These meetings are designed as a nurturing ground for a vibrant community network where parents can freely exchange experiences, insights, and advice. The aim is to create an atmosphere that is not just welcoming but also empowering, ensuring every parent feels at ease to voice their thoughts and share their stories. By facilitating such interactions, PREP meetings become a catalyst for forming supportive relationships and fostering a sense of belonging among parents. Keeping in mind that fostering these relationships with parents leads to a stronger support system for student success in their STEM education journey.

A key aspect of these gatherings is to encourage mentorship and emotional support amongst parents themselves. This peer-to-peer mentorship is invaluable, offering a lifeline to those feeling isolated or daunted by the challenges of navigating their child's STEM education journey. Whether it's guiding new parents through the educational landscape, sharing strategies for common challenges, or connecting over shared cultural experiences, the emphasis is on building a supportive network that thrives on mutual assistance and understanding.

Furthermore, these meetings serve as an outlet for parents to directly influence broader STEM educational strategies. By setting up forums and channels, ranging from online surveys and in-person discussions to suggestion boxes, for parents to contribute their perspectives, the initiative ensures all perspectives are valued. This inclusive approach not only brings diverse insights into curriculum development and educational planning but also reinforces parents' roles as valued

stakeholders in the STEM educational community. Through these concerted efforts, PREP meetings exemplify a proactive approach to integrating parents into the center of STEM education, underscoring the vital role of family influence in shaping an enriching and inclusive STEM learning landscape.

5.2.9 Step 9: Recognize and Celebrate Contributions and Achievements in STEM

Recognizing and celebrating the contributions and STEM achievements of parents and families becomes a critical component of fostering a vibrant school STEM community. Developing a consistent and inclusive strategy for acknowledging the varied contributions of parents ensures that every act of involvement, from assisting with school STEM activities to encouraging STEM learning at home, is valued. This approach not only builds a positive school culture but also emphasizes the integral role of parental involvement in enhancing their children's educational pathways in STEM.

Incorporating success stories and significant contributions into school publications serves a dual purpose. It recognizes the efforts of parents and families while simultaneously inspiring others within the community to participate actively. By highlighting these achievements, particularly those that reflect the cultural diversity of the school community, a stronger sense of belonging and pride is cultivated among all families. These narratives become powerful affirmations of the community's collective strength and commitment to fostering an inclusive and supportive STEM learning environment.

Moreover, acknowledging both students' and parents' achievements through various platforms, such as school assemblies, newsletters, or the issuance of digital certificates, plays a pivotal role in sustaining engagement with STEM subjects. Celebrating these milestones not only instills a sense of accomplishment but also motivates continued involvement and exploration

within the STEM fields. Through such recognition, the school not only honors the contributions and achievements of its community members but also strengthens the collaborative bond between the school, its students, and their families, thereby advancing the shared goal of making STEM education more accessible and enriching for every student.

5.2.10 Step 10: Continuous Improvement Through Evaluation of PREP Initiatives

The ongoing evaluation of PREP efforts is vital. This step involves a structured assessment of the program's impact on enhancing student achievement in STEM and deepening parent engagement. By employing various metrics, such as student academic performance, attendance rates, and the extent of parental involvement in school STEM activities, educators can gain valuable insights into the effectiveness of PREP initiatives. Such evaluations serve not only to measure success but also to identify opportunities for enhancing the STEM educational experience for students and their families.

Leveraging the insights gained from these assessments, schools can dynamically refine and adjust PREP strategies. This adaptive approach allows for the scaling of successful practices and the reevaluation of less effective ones, ensuring that the program remains responsive to the evolving needs of the school STEM community. This process of continuous feedback and improvement reveals the STEM program's commitment to fostering a STEM educational environment where both students and parents feel supported and valued.

To facilitate this cycle of feedback and refinement, employing straightforward tools like online surveys and feedback forms can be particularly effective. These instruments enable the direct collection of input from parents and students, providing a rich source of data to inform the ongoing development of the PREP initiative. By actively seeking and incorporating community feedback into the planning and improvement efforts, schools can ensure that their STEM programs

are deeply connected to the community's cultural values and aspirations. This step reaffirms the overarching goal of Chapter 5: to cultivate a STEM education landscape that is accessible, inclusive, and empowering for every member of the school's STEM community.

5.3 CONCLUSION:

Chapter 5 has laid out a comprehensive guide for implementing the Culturally Attuned Parent Engagement (CAPE) in STEM Education, tailored to meet the various needs of underserved communities, particularly within the context of working-class Hispanic families in West Texas. This guide has not only demonstrated the pivotal role of parental involvement in fostering an accessible, engaging, and culturally resonant STEM education. It also highlighted a systematic approach to building and sustaining this involvement through the Parent Resource Engagement Program (PREP). Fostering this collaborative ecosystem supports student success and also cultivates a culture of engagement, collaboration, and empowerment across underserved communities. Furthermore, the PREP guide emphasizes the importance of starting with foundational efforts, such as providing accessible STEM resources and establishing a small dedicated team. It progressively builds towards more complex strategies like integrating real-world STEM contexts and celebrating achievements within the STEM community. The journey outlined illustrates a dynamic and responsive approach to STEM education, acknowledging that the essence of meaningful engagement lies in understanding and respecting the cultural, linguistic, and practical realities of underprivileged families.

The message is clear: fostering a culturally attuned STEM educational environment is a collaborative and evolving effort. It requires the commitment of educators, parents, and community stakeholders alike. The steps detailed in the PREP guide serve as a blueprint for initiating this transformative journey, with the ultimate goal of ensuring every child has the

opportunity to explore, learn, and excel in STEM fields, supported by a community that values and invests in their potential. In conclusion, Culturally Attuned Parent Engagement is not just a set of steps; it is a transformative approach that has the potential to revolutionize the STEM educational landscape. It is a testament to the power of inclusivity, collaboration, and recognizing the diversity that makes up our school communities. By embracing this approach, schools are not only promoting STEM academic success but also building stronger, more inclusive communities that will leave a lasting impact on generations to come.

Chapter 6: How-to Guide: Community Centered STEM Education

6.1 Introduction

In the evolving landscape of STEM education, Chapter 6 outlines an innovative approach known as Community-Centered STEM Education (CCSE), which strategically places the local community at the forefront of STEM learning initiatives. CCSE represents an adaptive shift, actively integrating community stakeholders, including members, leaders, businesses, and STEM-related industry partners, into the STEM educational framework. This collaborative model is designed to create a significant partnership between STEM school programs and the broader community, aiming to unlock new opportunities for students in underserved areas.

At the core of CCSE is the strategy of extending learning beyond the boundaries of the classroom, facilitating direct student involvement with real-world engineering challenges and practices. Through opportunities such as internships, job shadowing, apprenticeships, mentorships, and innovative STEM competitions like the "Congressional App Challenge," students gain valuable insight into the practical aspects of engineering fields. This hands-on learning approach not only clarifies the abstract concepts often associated with STEM but also illustrates the concrete impacts of engineering solutions in society.

Furthermore, CCSE incites the inclusion of real-world scenarios into enhancing the STEM curriculum, enabling partners to share their expertise and also present real-world STEM challenges. This collaboration ensures that the STEM education provided is both relevant and aligned with current industry practices in a variety of STEM fields. It equips traditionally underserved students with a thorough understanding of engineering principles, fostering skills such as problem-solving, critical thinking, and adaptability; essential qualities for tomorrow's engineers.

6.2 STEP-BY-STEP CCSE GUIDE

As we explore the steps of implementing CCSE, this chapter will act as a guide for STEM educators, industry professionals, and community leaders, outlining a path towards a more inclusive, dynamic, and impactful STEM education. By bridging the divide between theoretical knowledge and practical application, CCSE aims to nurture a generation of STEM students who are not only proficient in STEM disciplines but also prepared to make meaningful contributions to their communities and the broader world.

This chapter emphasizes the commitment to transforming STEM education into a pathway for community empowerment and innovation, paving the way for underserved students to explore, learn, and excel in a world where technology and engineering are critical to societal progress. Through the framework of CCSE, we embrace the challenge of preparing students for the complexities of the future, ensuring they are equipped to navigate, contribute to, and lead in an ever-changing global setting.

6.2.1 Step 1: Identify Community STEM Partners

Initiating the CCSE component requires a focused strategy to identify key STEM partners in the community. This involves mapping local businesses, educational institutions, community organizations, and leaders who are crucial in providing a rich STEM learning experience, particularly for students in underrepresented communities. The goal is to identify potential mentors and partners equipped with the expertise and resources necessary for enhancing STEM education. The strategic identification enables the CCSE initiative to utilize local resources and expertise. This creates a STEM education program that addresses immediate student challenges, such as limited access to quality resources and career guidance.

6.2.2 Step 2: Build Collaborative Partnerships

After identifying potential STEM partners, the next step is to forge strong relationships that link educational STEM settings with the broader STEM community's resources and opportunities. This crucial step engages local STEM organizations, businesses, and community leaders, inviting them to play an instrumental role in enriching STEM education. These partnerships serve as vital links, channeling funding, mentorship, equipment, and practical challenges directly to underrepresented students, thereby transforming abstract concepts into concrete, real-world applications.

Creating these relationships necessitates the development of common goals and visions that resonate with both the academic sector and the surrounding community. This process aligns the educational STEM program with the interests of local entities, encouraging businesses to invest in the development of their future STEM workforce and community leaders to appreciate the value of an educated and technologically proficient population. The collaboration fostered through these partnerships not only opens pathways for students to discover potential STEM careers but also tightly integrates their learning experiences with the community's immediate needs and opportunities. Integrating the expertise and resources of local partners into CCSE ensures that students' education is closely connected to real-world STEM applications, enhancing both their academic achievements and their future career prospects.

Moreover, this joint effort enriches the educational STEM experience with a variety of learning opportunities, such as internships, project-based learning, and community service projects. These experiences not only broaden students' educational journeys but also embed them within their community, preparing them for active participation and professional roles in society. Through the sharing of ideas and innovations among different sectors, the CCSE component

thrives, enriched by a diversity of perspectives and solutions tailored to contemporary educational STEM challenges.

6.2.3 Step 3: Develop a Relevant STEM Curriculum and Participate in STEM Competitions

This step involves integrating real-world community issues and projects into the STEM curriculum which serves as a bridge connecting students' learning with tangible engineering principles. By focusing on challenges directly tied to their local environments, students are not merely passive recipients of information but active participants in engineering solutions that resonate with their immediate surroundings. This methodological approach not only highlights the relevance of their STEM education but also cultivates a profound sense of community involvement and responsibility.

Engaging students in community-centric projects is a powerful means for demonstrating the practical application of engineering principles. Whether it's designing water purification systems to address local water quality issues, developing sustainable energy solutions for community facilities, or creating software applications to improve local services, these projects allow students to apply engineering methodologies to solve pressing problems. Through this immersive experience, students transition from theoretical learning to applying knowledge in real-world contexts, thereby solidifying their understanding of engineering concepts while enhancing their problem-solving, critical thinking, and collaborative skills. These competencies are not only pivotal for students' future careers in STEM fields but also for their active civic engagement and contributions to community resilience.

Moreover, the inclusion of STEM competitions, such as robotics competitions or the "Congressional App Challenge," provide an additional layer of experiential learning. These STEM

competitions challenge students to invent prototypes and apply their engineering knowledge creatively, offering a platform for them to present innovative solutions that could have significant community impacts. Participation in such events not only encourages students' confidence in their problem-solving abilities but also amplifies the practical significance of their STEM education, bridging classroom concepts with real-world applications.

This hands-on approach to learning, accentuated by the integration of engineering principles through community-engaged projects and STEM competitions, transforms the STEM curriculum into a dynamic, interactive, and impactful journey for students. It propels them to take ownership of their education, viewing themselves not just as learners but as important contributors to their community's well-being. This step helps ensure students are better prepared to navigate the complexities of the modern world as informed, skilled, and compassionate engineers ready to innovate for the betterment of their communities and beyond.

6.2.4 Step 4: Engaging Local STEM Experts and Role Models

Inviting experts from the community's STEM workforce into the classroom introduces students to the real-world implications of their STEM studies, offering them a glimpse into potential STEM career paths as well as their everyday relevance. This step is specifically focused on enhancing career readiness. Collaborations with local STEM industries can facilitate internship and apprenticeship opportunities, seamlessly connecting theoretical knowledge with its application in the professional sphere. These experiences not only solidify students' understanding of STEM but also equip them with skills and insights valued in the local job market, better aligning educational outcomes with community workforce needs.

The introduction of community experts into the learning environment serves as a catalyst for igniting students' passion for STEM, providing them with a vivid picture of what their futures

could hold. Engaging with STEM professionals who navigate the challenges and opportunities of STEM related jobs can help lead the path to career success, offering students practical guidance and support. This direct interaction with role models showcases the diversity of STEM careers, helping students to envision themselves in similar roles. Tailored educational STEM experiences, such as workshops led by these experts, provide invaluable hands-on learning opportunities, further solidifying students' interest and competence in STEM.

Highlighting local STEM role models, whether through classroom discussions, school events, or social media platforms, plays a pivotal role in inspiring students and reinforcing their belief in their potential. Sharing success stories of individuals who have emerged from similar backgrounds to achieve success in STEM fields not only motivates students from underserved areas but also strengthens their connection to the community. These stories serve as powerful testaments to the attainability of success in STEM, encouraging students to pursue their interests with confidence and determination. This step fosters a supportive and inspiring educational STEM environment where students are prepared to meet the challenges of the future, armed with knowledge, skills, and a profound sense of community belonging.

6.2.5 Step 5: Create STEM Community Events

Organizing STEM community events and science fairs are essential to showcasing the real-world applications of engineering principles while simultaneously developing essential soft skills in students. These platforms provide students with the opportunity to present STEM projects that not only demonstrate their technical skills but also require them to engage in critical thinking, problem-solving, and innovative design, key aspects of engineering education.

Beyond the technical skills, these events are instrumental in developing students' soft skills, such as communication, teamwork, and leadership. Presenting their projects to the community,

students learn to articulate complex engineering concepts using industry terms and enhancing their ability to communicate effectively with diverse audiences. Collaborating on projects for these events also strengthens their teamwork skills, as they must work together to brainstorm solutions, delegate tasks, and bring their collective vision to completion. Leadership skills are refined as students take charge of their STEM projects, guiding their peers through the engineering design process and making strategic decisions to overcome obstacles.

This dual focus on technical and soft skills development, within the context of community engagement, reinforces the CCSE mission of preparing students for future academic and professional endeavors. These events become a celebration of student achievement, a demonstration of the practical value of their education, and a testament to the power of collaborative, community-focused learning in fostering a generation of well-rounded, community-oriented STEM leaders.

6.2.6 Step 6: Establish Mentorship Programs with STEM Professionals

In alignment with the principles of CCSE, establishing mentorship programs that bridge students with local STEM professionals stands as a crucial stride towards enriching the STEM learning environment. Such programs are designed to not only illuminate the diverse career paths within the STEM disciplines but also to provide students with personalized guidance, career insights, and practical experiences in the field. By facilitating these connections, this step illuminates the journey to becoming a STEM professional, showcasing the range of opportunities and the real-world impact of STEM careers. This initiative reflects the commitment to fostering a learning environment where students can directly benefit from the wisdom, experience, and encouragement of mentors who are actively engaged in the STEM professions.

These mentorship programs, encompassing job shadowing, internships, and apprenticeships, are pivotal in granting students firsthand exposure to the STEM workforce. Such immersive STEM experiences enable students to apply classroom knowledge in professional settings, thereby enhancing their understanding of engineering principles, scientific inquiry, and technological innovation. Moreover, these opportunities allow students to witness the day-to-day challenges and rewards of STEM careers, fostering a deeper appreciation for the field and its contribution to society. The hands-on experience gained through these programs equips students with valuable skills and insights, making their STEM education more tangible and relevant. It also serves to inspire students by providing them with role models and guiding figures who exemplify the potential paths their futures could take.

These programs create a collaborative network where STEM professionals can impart their knowledge and expertise to the next generation, thereby investing in the community's future. Furthermore, this approach fosters a culture of lifelong learning and curiosity among students, encouraging them to explore, question, and innovate. Mentorship programs embody the essence of CCSE by creating a supportive, engaging, and dynamic learning environment that prepares students for the complexities of the modern world, ensuring they are ready to contribute meaningfully to their communities and beyond in their possible future STEM careers.

6.2.7 Step 7: Establishing a STEM Alumni Network

This step involves creating a platform or network that connects current STEM students in with alumni who have pursued careers in STEM fields. By establishing a STEM Alumni Network, STEM programs can provide students with access to mentors, role models, and resources to support their academic and career journeys in STEM. Alumni can offer valuable insights,

guidance, and support to current students, sharing their experiences, career paths, and advice on navigating the STEM journey.

Through the STEM Alumni Network, students can benefit from mentorship opportunities, networking events, career panels, and informational interviews with alumni who have successfully transitioned into STEM professions. Alumni can serve as inspirational figures, demonstrating the possibilities and pathways available in STEM fields, particularly for individuals from similar backgrounds or educational settings. Specifically, this can help support parents by illuminating the path to higher education for families who may be navigating this process for the first time. By fostering connections between current students and STEM alumni, schools can develop a sense of community and empower them to pursue their interests and aspirations in STEM disciplines.

6.2.8 Step 8: Engaging in Collaborative Fundraising Efforts with Community Partners

This involves initiating collaborative fundraising efforts with local businesses, community organizations, and potential sponsors to secure financial support for STEM education initiatives. By partnering with external stakeholders, schools can raise funds to enhance STEM programs, acquire essential resources, and provide students with valuable learning opportunities. Fundraising activities may include organizing community events, seeking sponsorships from businesses, applying for grants, or launching crowdfunding campaigns tailored to the specific needs of the school.

Engaging in collaborative fundraising not only helps alleviate financial constraints but also fosters a sense of shared responsibility and investment in STEM education within the community. By leveraging the support of partners, schools can expand their resources, create innovative learning experiences, and empower students to excel in STEM fields despite limited financial

resources. Through strategic fundraising partnerships, schools can strengthen their STEM initiatives and promote a culture of community involvement in advancing STEM education.

6.2.9 Step 9: Measuring and Communicating the Impact of CCSE

In this step, it is important to assess and articulate the impact of the CCSE initiatives, serving as a testament to the transformative power of integrating community resources and perspectives into STEM education. This evaluation involves a systematic collection of data on student outcomes, community engagement, and the overall effectiveness of the STEM program. By tracking metrics such as student academic performance, participation in STEM-related activities, and the broader community's feedback, STEM educators can gain a comprehensive understanding of how CCSE initiatives are shaping students' learning experiences and their connection to the community. This process not only highlights the STEM educational value of these programs but also provides essential evidence to gather continued support, resources, and funding, ensuring the sustainability and growth of the STEM program.

Communicating the successes and milestones achieved through CCSE is crucial in reinforcing the community's investment in STEM education. By sharing these achievements through various channels like newsletters, local media, and public events, the program strengthens the ties between schools and the community, fostering a sense of pride and collective ownership over the advancements made in STEM education. These narratives of success serve as powerful catalysts for inspiring further engagement and support from community members, highlighting the tangible benefits of CCSE and its role in fostering a future generation equipped with critical STEM skills and knowledge.

Celebrating the accomplishments of students, educators, and community partners involved in CCSE initiatives not only amplifies the impact of these efforts but also cultivates a

culture of excellence and innovation in STEM within both the school and the broader community. Showcasing student projects, achievements, and the overarching success of the CCSE program reinforces the importance of STEM education and its applicability to real-world challenges. Such celebrations are instrumental in motivating students, attracting additional partnerships, and inspiring ongoing community engagement, laying the groundwork for a thriving environment where STEM education flourishes, driven by collaborative efforts and a shared vision for a brighter, more innovative future.

6.2.10 Step 10: Continuous Improvement

This step is about continuous improvement of CCSE, necessitating regular assessments and the flexibility to refine initiatives in response to data, feedback, and evolving community needs. This iterative process of evaluation involves reviewing the outcomes of CCSE initiatives, taking into account student performance, participation rates, and the feedback gathered from all stakeholders. By staying aware of both successes and areas requiring improvement, CCSE remains dynamic, ensuring its initiatives are effective.

In pursuit of elevating the CCSE model, it is crucial to remain observant for opportunities that push the boundaries of traditional STEM education. This effort requires staying on top of the latest STEM educational trends, technological advancements, and innovative teaching methods. The aim is to continually seek ways to enrich and expand CCSE initiatives, whether through the incorporation of cutting-edge technologies, broadening community partnerships, or engaging in innovative community engagement strategies. Such forward-thinking ensures that CCSE remains at the forefront of STEM educational innovation, providing students with a learning experience that is both relevant and transformative.

Implementing a structured system for ongoing evaluation and feedback is essential for the iterative refinement of CCSE initiatives. This framework ensures that insights from students, parents, educators, and community partners are not just heard but actively inform the evolution of the STEM program. Utilizing this feedback to make informed adjustments captures the essence of continuous improvement, fostering a STEM educational environment that is responsive, innovative, and tailored to meet the diverse needs of the community. Through this relentless pursuit of excellence, CCSE solidifies its role as a catalyst to improve STEM education, shaping an ecosystem where STEM education thrives, powered by community collaboration and a shared commitment to nurturing future generations of problem solvers and innovators.

6.3 CONCLUSION:

In summary, establishing collaborative partnerships within the CCSE framework is about creating a dynamic educational STEM environment where learning extends beyond traditional boundaries, engaging students in meaningful STEM experiences that reflect and respond to their community. These partnerships are a declaration of the community's dedication to creating an atmosphere where every student can reach their full STEM potential, supported by a network of local supporters committed to their success.

CCSE fosters a strong and mutual connection between STEM learning and the local community, creating deeply meaningful and relevant educational STEM experiences. By actively engaging community members, leaders, businesses, and industry partners and leveraging available community resources, CCSE aligns STEM education with the unique strengths, needs, and assets of the community, enriching the educational STEM journey for underserved students.

By following the steps outlined and prioritizing community involvement and partnerships, the STEM program can help cultivate a sense of ownership and pride in both students and the

community. This approach not only equips students with essential STEM skills but also empowers them to become active contributors to the prosperity and sustainability of their community. Moreover, CCSE paves the way for local STEM businesses and industry to actively participate in shaping the future STEM workforce, fostering mutually beneficial relationships that promote economic growth and community development.

In essence, Community Centered STEM Education transcends traditional educational boundaries, making STEM education an integral part of community life. Through this approach, a lasting and positive impact on both students and the community can be created, ensuring that STEM education becomes a vital catalyst for progress and opportunity within the underserved community.

Furthermore, CCSE emphasizes the importance of adaptability and responsiveness, enabling STEM programs to evolve with the community's changing dynamics. Regular assessment and refinement of STEM programs ensure that STEM education remains relevant and responsive to technological advances and shifting economic demands. It also means that CCSE can be a means for social change, addressing inequities in education and workforce development, and offering all students, regardless of their background, a chance to thrive on path to a future STEM career.

The success of CCSE can serve as a blueprint for other communities, proving that when education is community-centric, it can bring about profound and widespread benefits. As schools share their experiences and learn from one another, the impact of CCSE can grow exponentially, leading to a more STEM educated, skilled, and prepared society. With the commitment to continuous improvement and the willingness to embrace innovative approaches, Community Centered STEM Education has the potential to transform not just individual communities but the broader landscape of STEM education worldwide.

Chapter 7: Assessing the Impact of the E3 Framework

7.1 Introduction

This chapter focuses on creating assessment tools for the evaluation phase of each component in the E3 framework, including specific indicators of success for each component, data collection timelines, and the process for iteratively refining the framework based on feedback and findings. Once desired steps are selected from each component, the assessment will apply exclusively to those chosen steps. This approach emphasizes gradual improvement and iterative refinement, making the task of assessment a constructive part of the process rather than an overwhelming challenge. It supports the commitment to continuous learning and adaptation, guided by feedback and outcomes, to progressively enhance STEM education in alignment with the framework's objectives. By assessing the impact of these steps, we can measure progress, identify areas for improvement, and ensure the success of community-centered STEM education programs.

7.2 Social Cognitive Theory

As discussed in the literature review, we know that Social Cognitive Theory delves into the reciprocal interaction between personal factors, behavior, and the environment. Central to this theory is the concept of self-efficacy, which is an individual's belief in their ability to succeed in specific situations. This theory is particularly relevant in understanding the motivational aspects of learning. In STEM education, self-efficacy can be a determining factor in students' choices to pursue STEM careers, their persistence in challenging tasks, and their resilience in the face of academic adversity. Additionally, Social Cognitive Theory highlights the significance of observational learning, where individuals acquire new behaviors and skills by observing others and the outcomes of their actions.

This type of learning is powerful in educational settings, as students can observe peers and teachers demonstrating successful behaviors and strategies. Therefore, STEM educators can leverage observational learning by offering students opportunities to observe and learn from positive role models. Through the integration of Community-Centered STEM Education, community partners can become positive role models for students. By integrating observational learning into their teaching methods, educators can facilitate the development of new skills and behaviors that enhance students' academic achievements. The study explores how different teaching methods, peer interactions, and learning environments influence students' self-efficacy in STEM. Enhancing self-efficacy in STEM education is directly tied to social sustainability. It promotes individual agency and confidence, essential for active participation in a sustainable society. High self-efficacy can lead to a more skilled workforce, contribute to economic growth, and enable individuals to make informed decisions about societal and environmental issues.

7.3 Assessing E3 Framework Impact

This section sets the stage for understanding the E3 Framework's broader impact, preparing for the detailed assessment methods outlined in section 7.4. It establishes the groundwork for selecting specific components to be assessed, highlighting the importance of strategic evaluation in driving the framework's continuous improvement.

7.3.1 Evaluation Plan:

- Define specific indicators of success for each component, such as increased student engagement (I^2RA), higher levels of parental involvement (Culturally Attuned Parent Engagement), and tangible community benefits (Community-Centered STEM Education).

- Outline data collection timelines, ensuring ongoing assessment and timely feedback incorporation.
- Describe the iterative refinement process, detailing how feedback and findings will be used to continuously improve the framework components.

7.3.2 Feedback and Refinement:

- Establish mechanisms for collecting stakeholder feedback, including digital platforms, regular meetings, and anonymous surveys.
- Define a structured process for analyzing feedback, prioritizing actions, and implementing changes to the framework.
- Schedule periodic review sessions with all stakeholders to discuss progress, challenges, and opportunities for further refinement. Quarterly meetings are suggested.

7.4 Assessment Tools

7.4.1 Instruction-Initiated Resource Activation (I^2RA)

- Pre- and Post-Survey of STEM Attitudes and Self-Efficacy: Develop surveys to gauge changes in student attitudes towards STEM and self-perceived abilities before and after I^2RA interventions. Key areas could include interest in STEM careers, confidence in handling STEM subjects, and perception of STEM's relevance to their lives.
- Classroom Engagement Metrics: Use classroom observation tools to quantify changes in student engagement during I^2RA activities. Metrics could include student participation rates, on-task behaviors, and instances of collaborative problem-solving.
- STEM Performance Metrics: Analyze student performance in STEM subjects through standardized test scores, project evaluations, and class grades before and after the implementation of I^2RA strategies.

7.4.2 Culturally Attuned Parent Engagement (CAPE)

- Parental Involvement Index: Create a tool to measure the frequency and quality of parental involvement in students' STEM education, including attendance at school events, participation in STEM-related home activities, and communication with teachers.
- Parent and Teacher Surveys: Conduct surveys to assess the perceived effectiveness of CAPE initiatives on student outcomes and parent-school relationships. Include questions about the relevance of activities, ease of participation, and suggestions for improvement.
- Student Reflections on Parental Support: Collect qualitative data from students about the impact of increased parental involvement in their STEM education, focusing on motivational and emotional support aspects.

7.4.3 Community-Centered STEM Education (CCSE)

- Community Engagement and Impact Assessment: Develop a tool to evaluate the depth and breadth of community engagement in CCSE initiatives, including the number of community partnerships, community-based project implementations, and local STEM event participations.
- STEM Career Pathway Awareness Survey: Survey students to measure their awareness and interest in STEM careers before and after CCSE interventions, noting any changes in career aspirations related to community partnerships and mentorships.
- Longitudinal Tracking of STEM Pathways: Implement a system to track students' progression into STEM pathways, including enrollment in advanced STEM courses, participation in STEM competitions, internships, and post-secondary STEM education or careers.

7.5 CONCLUSION

These assessment tools should be tailored to the specific objectives and activities outlined in each chapter, providing a comprehensive understanding of the impact of each program component on students, parents, and the broader community. Regular review and adjustment of these tools will ensure they remain effective in capturing the intended outcomes of the I^2RA, CAPE, and CCSE frameworks.

By developing comprehensive assessment tools for evaluating the implementation of STEM initiatives in West Texas schools, we can ensure that these programs are making a meaningful impact on the community. Through ongoing assessment and feedback, we can continuously improve and refine our approaches to promote social sustainability and empower underrepresented communities through dynamic STEM education initiatives.

Chapter 8: Case Study: Application of Theory

8.1 Introduction

In the previous chapters, we explored an interdisciplinary framework designed to utilize STEM education as a tool highlighting its critical role in fostering social sustainability and empowering communities. Chapter 8 further explores a tangible manifestation of this theoretical construct through the "Elevate to Empower" program, a pioneering initiative aimed at uplifting economically underserved Hispanic communities in West Texas. This case study not only showcases the practical application of the interdisciplinary E3 framework but also focuses its effectiveness in achieving measurable improvements in student outcomes and community empowerment. Through the lens of the "Elevate to Empower" program, this chapter seeks to highlight the transformative potential of integrating STEM education as a tool with environmental engineering practices to create more sustainable and equitable prospects.

8.2 Program Goals and Overview

The "Elevate and Empower" Initiative, in collaboration with the NASA MUREP Aerospace Academy for the Southwest (MAA Southwest) at UTEP, targets economically underserved Hispanic communities to inspire and prepare high school students for STEM fields, with a focus on engineering. This initiative offers experiential learning opportunities, culturally attuned family engagement, and career readiness support within a context marked by economic challenges and educational disadvantages.

8.2.1 Program Context:

The MAA Southwest program spans an 8-county region around West Texas. Its focus is on addressing the cycle of poverty and educational disadvantage by providing free hands-on STEM learning experiences and exposing students to aerospace along with other engineering careers.

This approach tackles the lack of exposure to enriching STEM education and overcomes geographic barriers in rural and underserved communities. Highlighting experiential learning and direct engagement with STEM professionals, the program aims to inspire students into STEM careers. Additionally, they provide a field trip to the UTEP Aerospace Center research facilities as well as mentoring opportunities with industry experts.

8.3 PROGRAM STRATEGY IMPLEMENTATION

8.3.1 Tailored Strategies for Elevate and Empower STEM Camp

After evaluating program options, the E3 Framework was selected to ensure this camp would be successful. This led to the immediate planning and launch of the "Elevate and Empower" STEM camp, held during the summer. This new program integrated specific strategies from each of E3's Framework components to more effectively address the barriers previously identified. The goal was to significantly enhance student engagement and interest in STEM fields, empowering students to overcome obstacles and achieve their educational and career aspirations. Particular strategies from the E3 Framework's components were carefully selected and customized to align with the unique needs of the camp, ensuring that the actions implemented directly contributed to the larger objective of promoting social sustainability and empowering the community.

8.3.2 Strategies selected from Chapter 4: Instruction-Initiated Resource Activation (I^2RA)

1. Identify Goals and Objectives (Step 1 from Chapter 4): The case study involved setting clear goals and objectives for the construction of the designed STEM program. The overarching goal aimed at improving the STEM educational disparities faced by these communities, with a specific objective to leverage local resources, engage community stakeholders, and implement targeted STEM education initiatives to enhance learning opportunities and outcomes for students within the underserved area. The goals and

objectives were identified by collecting essential feedback through surveys, direct observations, and meetings with students, parents, and two teachers from Presidio High School.

2. Engage Stakeholders and Assess Resources (Step 2 from Chapter 4): Stakeholders, including local businesses and community leaders, were engaged to assess and gather resources for the STEM initiatives. Feedback gathered from Step 1, along with a proposed format for the E3 model's implementation, was presented and analyzed in a meeting. A team of higher education staff reviewed and endorsed the proposal and requested additional factors to meet grant necessities but these additions did not change the E3 framework or application in any way.
3. Develop an I^2RA Plan (Step 3 from Chapter 4): A structured interdisciplinary plan was created to utilize community resources and effectively support the "Elevate and Empower" program. The detailed plan included the following tasks:
    - Transport students from Presidio to and around El Paso during the summer
    - Provide 3 meals per day
    - Expose students to university life as well as one other higher education partners
    - Enhance STEM Education: Implement a summer camp tailored to the unique needs of Presidio students, focusing on hands-on activities and interaction with engineering professionals partnered with the UTEP Aerospace Center, aiming to bridge the knowledge gap and ignite a passion for STEM. Incorporate community-centered STEM challenges.
    - Financial and Career Guidance: Provide intensive support to navigate applying for educational funding therefore, acknowledging the financial hurdles faced by

students. Additionally, explore different engineering careers within the aerospace industry.

- UTEP Dormitory Experience: Immerse students in university life and foster a sense of belonging. Allowing students to reside in UTEP dormitories, and experiencing the academic and social atmosphere firsthand.
- Immediate Mentorship: Mentorship by engineering college student researchers to offer guidance and support, serving as relatable role models to inspire high school students on their educational STEM journey.

The camp protocol included transporting participants to and from Presidio, ensuring the presence of a trusted chaperone in the dorms, and providing all daily meals. Academically, it involved creating the STEM curriculum, collaborating with the mentor research assistant, and organizing university related appointments.

4. Resource Mapping and Protocols Establishment (Step 4 from Chapter 4): The "Elevate and Empower" program involved mapping out local resources that could support STEM learning. The local resources that were attained included:
    - Classroom space at Western Technical College
    - Use of 8-Dremmel 3D printers provided by Western Tech
    - Use of a UTEP van with a gas card provided by the UTEP Aerospace Center
    - Use of UTEP dining facilities provided by the UTEP Aerospace Center
    - One college research assistant provided by the UTEP Aerospace Center
    - Meetings with financial aid, Upward Bound, and aerospace department
5. Raise Awareness and Communicate Benefits (Step 5 from Chapter 4): Active efforts to highlight the benefits of the STEM camp via social media and local news outlets

significantly raised community awareness. These initiatives caught NASA's attention, resulting in an invitation to present the E3 framework at the annual NASA Better Together Conference.

6. Evaluate and Reflect (Step 7 from Chapter 4): The program goal, established in Step 1, was then evaluated to see if it resulted in a successful outcome. The goal was achieved, enhancing learning opportunities and outcomes for students within the underserved area. This success stemmed from improving targeted STEM educational disparities faced by the community, with efforts specifically aimed at leveraging local resources, engaging community stakeholders, and implementing targeted STEM education initiatives.
7. Share Success Stories (Step 8 from Chapter 4): During NASA's annual Better Together Conference, NASA Directors received updates on the successful outcomes of the "Elevate and Empower" program. They were briefed on how the E3 framework, serving as the core structure of this innovative program, was effectively implemented. The presentation provided decision-makers with tangible examples that their grant investments were effectively utilized, and highlighted the program results.

8.3.3 Strategies selected from Chapter 5: Culturally Attuned Parent Engagement (CAPE)

1. Enhance Parental Support in STEM Initiatives (Step 1 from Chapter 5): The program focused on fostering parental involvement in their children's STEM education, recognizing parents as essential partners in this endeavor. To prepare for the STEM program, detailed itineraries featuring links to university resources were sent via email to the administration one month ahead of the program, specifically for approval and then distribution to parents. This included information that would be shared with students during the program such as financial aid and scholarships, demographics of the university, first generation

organizations, and detailed STEM career pathways. These specific resources were selected to directly address the unique interests, concerns, and aspirations of the students and their families. The selection aimed to illuminate the path to higher education in STEM.

Parents were individually contacted to address any questions, and the chaperone's cell phone number was shared, ensuring they could get in touch at any time before, during, or after the program if they had any questions or concerns. As a result, 100% of the parents engaged in direct communication and all expressed sincere gratitude ahead of the program implementation. The direct and personal communication significantly reassured parents that their students would receive comprehensive support for college and career planning.

Additionally, families were observed participating in the process of dropping off students for the STEM program pick-up. It's crucial to emphasize the significance of the term "families" in this context, as it wasn't merely the parents who participated in dropping off the students, but entire family units. This collective involvement serves as a prime example of the community's holistic approach to supporting educational journeys, highlighting the depth of communal investment in each student's success in STEM fields. In the tight-knit Hispanic community, the act of additional family members dropping off the students showcased a clear example of the framework's emphasis on family involvement. Moreover, family members provided encouragement not only to their own children but to all the students, demonstrating a strong sense of community support. This action further highlights the community's collective approach to supporting the educational and professional growth of each student, aligning with the framework's focus on family as a foundational element.

2. Assess Parents' Needs and Preferences (Step 3 from Chapter 5): Strategies were tailored to meet the cultural and practical needs of families, making engagement efforts more effective and meaningful. Parents were supplied with program information in both English and Spanish as well as communicated to in their Spanish native language. Phone calls and emails were conducted after 5pm to accommodate for working schedules. Traditionally, in other STEM programs, the transportation and meal costs were factors that prevented families from supporting their students' STEM education, so these expenses were covered. Furthermore, services were introduced to provide students with direct access to university-related information, including financial aid, student organizations, and engineering career paths. This was done to encourage students to consider continuing their education beyond high school after attending the camp.

8.3.4 Strategies selected from Chapter 6: Community-Centered STEM Education (CCSE)

1. Identify Community STEM Partners (Step 1 from Chapter 6): Identifying specific STEM partners within the community was a critical first step in implementing the CCSE component. Each partner listed in the CCSE component brings unique strengths and resources to the table, enhancing the educational STEM experience and contributing to the overall goals of the program. The partners identified included:
    - NASA: As a leader in space exploration and aeronautics research, NASA provides unparalleled access to cutting-edge science and engineering projects, offering students hands-on experience with space technology, internships, and mentorship opportunities with scientists and engineers.
    - UTEP: With its strong engineering and science programs, UTEP offers academic support, access to university laboratories and research facilities, and opportunities

for students to interact with college-level professors and undergraduates, fostering an early interest in higher education and research. UTEP also enriches the students' pathway towards higher education by offering critical support mechanisms, such as assistance in finding scholarships tailored to STEM students' needs. UTEP's dedicated programs for first-generation college students provide invaluable resources and guidance, making the prospect of university education more accessible and achievable.

- Western Tech: Having partnered with the UTEP Aerospace Center, this technical school has established an aerospace certification. Seeing the progression from technical certifications to advanced engineering roles can reinforce the value of higher education. This understanding can solidify students' aspirations to attend the university, pursuing degrees that offer pathways to leadership and innovation in aerospace engineering and related fields.
- Blue Origin: As a company at the forefront of private space exploration and rocket development, Blue Origin exposes students to the latest in aerospace technology and engineering practices. Hearing from previous UTEP Aerospace Center students who are now engineers at Blue Origin could encourage them to pursue careers in aerospace engineering. Additionally, given its proximity to El Paso, gives students an option to stay close to their families.
- Mija, Yes You Can: This nonprofit organization, focuses on empowering young women, and providing encouragement for female students. They offer workshops, speaker series, and support networks to help overcome gender disparities, promoting diversity and inclusion.

- UTEP Engineering Professors: Professors from UTEP bring academic rigor and expertise to the program, offering guest lectures, conference opportunities, curriculum development assistance, and guidance on latest engineering challenges and solutions. Their involvement ensures that the STEM curriculum is both current and comprehensive.
- Local STEM Educators: Experienced STEM educators, particularly those with a background in innovative teaching methods and community-based education, are crucial for designing engaging, relevant, and effective STEM learning experiences. They also act as liaisons between the various partners and the students, ensuring that educational goals are met.

Each partner's contribution is aligned with the overarching goal of enhancing equity, cultural diversity, and community empowerment through STEM education. By leveraging the unique resources, expertise, and opportunities these partners provide, the program aims to create a comprehensive and immersive STEM learning environment that inspires and equips students to pursue STEM careers and contribute to their communities.

2. Build Collaborative Partnerships (Step 2 from Chapter 6): Establishing partnerships with local organizations, businesses, and educational institutions was key to supporting the STEM education program and creating opportunities for students. These established partnerships were leveraged to provide STEM resources for the students including classroom guest speakers (Step 4), student research jobs and mentorship opportunities (Step 6), and funding and classrooms for the program (Step 8).

Each step was adapted to fit the context of the case study, with a focus on improving STEM education outcomes, engaging parents and the community, and utilizing local resources to support underrepresented students in STEM fields.

- **NASA**: Elevated the capstone project by supplying essential materials and integrating student researchers into the project, fostering a direct connection between academic learning and real-world space research. This partnership not only enriched the students' research experience but also bridged the gap between classroom learning and the cutting-edge work being done in the field of space exploration.
- **UTEP (University of Texas at El Paso)**: Delivered personalized guidance through programs specifically designed for first-generation college students, enhancing their access to financial aid and scholarship resources. UTEP's commitment extended to providing detailed information about the upward bound program, significantly supporting students' academic and career readiness by offering a tailored approach to navigating higher education challenges. Organizations met with students one-on-one.
- **Western Technical College**: Contributed a state-of-the-art facility equipped with eight 3D printers, creating a hands-on learning environment for students. The college further enriched the program by facilitating presentations from professionals who discussed STEM career paths, particularly those pertinent to the economic landscape of West Texas, thereby aligning educational content with local job market opportunities.
- **Blue Origin**: Brought in guest speakers, engineers with prior experience at the UTEP Aerospace Center, to share their journeys with students. These narratives of overcoming obstacles and achieving success in the aerospace industry provided invaluable

perspectives, especially for students coming from similar backgrounds, illustrating the possibilities that lie beyond academic challenges.

- **Mija, Yes You Can**: Actively engaged students with motivational sessions aimed at empowering female and minority students, addressing the underrepresentation in STEM fields. The organization highlighted mentorship opportunities as a key strategy for ensuring student success, promoting an inclusive environment that encourages perseverance and resilience.
- **UTEP Engineering Professors**: Engineering professors contributed their deep expertise to the program through guest lectures and offered students the unique opportunity to attend the 2nd IACM Mechanistic Machine Learning and Digital Engineering for Computational Science, Engineering, and Technology conference. They provided insights into contemporary engineering challenges and digital engineering solutions, thereby exposing students to the forefront of engineering innovation.
- **Local STEM Educators**: Served as vital connectors between the students and the various program partners, ensuring that the educational content and activities were well-aligned with the program's goals. These educators played a crucial role in student engagement, facilitating hands-on learning experiences that reinforced theoretical knowledge with practical application, thereby enhancing the overall educational impact.

8.4 METHODOLOGICAL APPROACH

The research methodology employed in this study is primarily qualitative with a quantitative element. The case study is an aerospace camp conducted by the UTEP Aerospace Center using the E3 framework as the basis and curriculum selection process for the camp. Results rely exclusively upon on secondary data sources. The data collection process involved an in-depth

analysis of existing surveys, interviews, classroom and community observations, and diverse educational materials, including program documentation, curricula, and reports, all derived from secondary sources. These methods of data collection, allowed for a multifaceted exploration of STEM education initiatives as reflected in the case study.

Ethical considerations, particularly around confidentiality, were rigorously upheld. To provide additional and precautionary measures all identifying information was meticulously removed to preserve anonymity and maintain ethical standards. The thorough analysis of this secondary data enriched the understanding of STEM educational practices within the case study context, ensuring the research's integrity and reliability while adhering strictly to ethical guidelines.

The analysis revealed key themes such as high satisfaction with the program's hands-on approach, enhanced engagement through real-world examples from renowned companies, the impactful role of mentorship and exposure to STEM professionals, and an appreciation for practical applications and problem-solving. Detailed insights include:

8.4.1 Student Feedback:

1. Satisfaction with the program: Students expressed high levels of satisfaction with the program, particularly valuing the hands-on learning experiences and the opportunity to engage with real-world applications of STEM. They appreciated the practical approach to learning, which allowed them to apply their knowledge to real-world scenarios.

2. Engagement with real-world examples: Students expressed high levels of engagement with the activities given that they were real-world examples connected to companies they are familiar with such as NASA, Blue Origin, and Lockheed Martin. This connection to real-world examples helped to increase their interest and motivation in STEM fields.

3. Impact of mentorship and exposure to STEM professionals: Feedback from participants highlighted the impact of mentorship and exposure to STEM professionals, which significantly contributed to their understanding of potential career paths. Students felt their questions were answered regarding specific career experiences that otherwise might not have been answered through a textbook. For example, one student stated that an employee from Blue Origin shared that employees are allowed to bring their dogs to work. The student stated that this this gesture indicated that the employer values them.

4. Appreciation for practical applications and creative problem-solving: The program's learning approach, emphasizing practical applications and creative problem-solving, was highly valued by the students. They found that engaging directly with real-world challenges, such as the capstone project on 3-D printed structures for extreme environments, not only enriched their understanding of engineering concepts but also developed their skills in the engineering design process. This project required students to analyze the unique conditions of the lunar environment, particularly the impact of extreme temperatures on materials, and apply additive manufacturing techniques to design viable lunar infrastructure, focusing on the development of wheels for use in such harsh conditions.

Through this immersive project, students learned to navigate the engineering design process from problem identification to prototyping and testing, a skill set that is crucial for their future careers. By iteratively designing wheels that could withstand the lunar environment's challenges, they practiced troubleshooting, critical thinking, and innovation. This experience demonstrated how the engineering design process is a powerful tool for solving complex problems, preparing them to tackle a range of future engineering

challenges, from sustainable construction on Earth to the development of habitats on other planets. The skills they developed, including effective teamwork and communication of their design ideas, are foundational to their success in any engineering endeavor, showing the far-reaching benefits of mastering the engineering design process.

Overall, the findings show that the program was successful in engaging students and providing them with valuable experiences and insights into STEM fields. Students suggested additional aspects to grow the program for future participants. Hands-on learning and increasing the frequency of interactions with STEM professionals were elements the students requested to receive additional time and opportunities to engage in. These findings can be used to inform the development of future STEM education programs.

8.4.2 Engagement Levels:

1. Active participation in activities: The program achieved remarkable engagement levels, with students actively participating in a range of activities, including project design, research, and presentations. Through their participation in the program's activities, students began asking questions about career paths in fields like materials engineering and biomedical engineering, uncovering interests in areas they previously didn't know existed. This active involvement indicates a high level of interest and motivation among the students.

2. Engagement during Capstone Project presentations: The Capstone Project presentations at the STEM Student Showcase event demonstrated high levels of student engagement and learning. During the capstone project, students researched into the details of 3D printing for creating structures designed to withstand the extreme conditions of the lunar environment, such as severe temperatures. They learned about the critical attributes of

engineering materials like Nitinol and how these properties influence material performance in space. Applying this knowledge, they engaged in the engineering design process to develop wheels optimized for operation in these harsh lunar conditions. This hands-on experience not only enhanced their understanding of material science and engineering principles but also equipped them with practical skills in designing solutions for real-world space exploration challenges. Students were able to effectively communicate their ideas and demonstrate a deeper understanding of the concepts taught. This demonstrates the students' ability to apply their knowledge of the engineering design process and communicate it effectively, reflecting a high level of engagement with the program.

3. Enhancement of engagement through field trips and interaction with STEM professionals: Field trips to NASA research facilities and W.M. Keck Center for 3D Innovation and interaction with STEM professionals further enhanced student engagement, offering real-world context to their learning. Students followed up with these new network connections to apply for internships and scholarship opportunities that they otherwise would not have heard about. This indicates that the program not only engaged students during the activities but also inspired them to pursue further opportunities in STEM fields.

4. Impact on career readiness and networking: The interaction with STEM professionals not only enhanced student engagement but also had a direct impact on their career readiness. Students utilized these connections to explore internship and scholarship opportunities, indicating that the program not only engaged them academically but also provided valuable networking opportunities for their future careers.

Overall, the program's ability to achieve remarkable engagement levels and provide opportunities for students to effectively communicate their ideas demonstrates its success in engaging students. Additionally, facilitating networking with STEM professionals demonstrates its effectiveness in preparing them for future opportunities in STEM fields. These findings can be used to further enhance the program's engagement strategies and networking opportunities for students.

8.4.3 Quantitative Measures of Success:

1. Achievement of recruitment goals and academic success: The program successfully reached its target of enrolling traditionally underrepresented students in STEM, meeting and in some areas exceeding its recruitment goals. Before the camp, the students indicated they were unsure about attending college and were less sure of a major. After the camp, 100% of the students in 12^{th} grade applied and were accepted to UTEP to study aerospace engineering. Additionally, students from other grade levels expressed their newfound desire to become engineers and their intentions to apply to UTEP. They attributed this interest and decision directly to their experiences at the camp. This demonstrates the program's success in not only attracting a diverse group of students but also in facilitating their academic progression into STEM fields at the university level.

2. Improvement in students' understanding and interest in STEM: Quantitative data showed a significant improvement in students' understanding and interest in STEM fields. This was evidenced by their active participation, quality of project work, and positive feedback. A structured evaluation method was utilized to measure progress and outcomes. Initially, students underwent a pre-camp assessment designed to establish a baseline of their knowledge and skills relevant to the project's focus areas, such as 3D printing techniques,

lunar environmental conditions, and the engineering design process. This assessment included both theoretical questions and practical problem-solving scenarios to accurately gauge their starting points.

Throughout the camp, students participated in a series of tests aimed at quantifying their growing understanding and proficiency. These tests were strategically administered at different phases of the project to measure incremental learning and application of concepts. For example, after the module on the properties of engineering materials in extreme conditions, a test assessed students' ability to select appropriate materials for lunar infrastructure projects based on environmental constraints. Another example was a debate set up to argue between the best material to use in the design of a lunar wheel. In addition to the structured tests and assessments, this debate on the best material for designing a lunar wheel offered rich quantitative data that complemented the overall evaluation of students' understanding and application of engineering concepts. A detailed rubric was utilized to assess various competencies including understanding of material properties, application of engineering principles, strength of research and evidence, clarity and structure of arguments, effectiveness of rebuttals and counterarguments, teamwork, and presentation skills. This rubric, meticulously designed to span a wide range of skills from technical knowledge to persuasive communication, allowed for a comprehensive quantitative measurement of student performance across these domains. Participants were scored in each category, with a total possible score of 100 points, highlighting not just their engagement with complex engineering challenges but also their proficiency in critical thinking, teamwork, and public speaking. The scores from this debate, analyzed alongside improvements in test scores and the quality of capstone projects, provided a multifaceted

view of the students' learning trajectory. The data derived from this rubric demonstrated significant improvement, underscoring the program's success in enhancing students' technical understanding as well as their ability to effectively communicate and defend their engineering decisions. This approach facilitated a holistic assessment of the educational experience, evidencing the program's efficacy in fostering a deep and practical understanding of engineering principles. Analyzing the debate's outcomes, particularly in the "application of engineering principles" category, the data revealed an impressive 30-point improvement which signifies marked enhancement in students' abilities to integrate theoretical knowledge with practical applications. Students better understood the use of certain engineering materials and concepts and also in the ability to justify their application choices effectively.

Upon completion of the capstone project, the students' work was evaluated against a rubric that considered several criteria, including technical accuracy, innovation in design, application of the engineering design process, and the ability to integrate learned concepts into their final project. Their designs of wheels for extreme environments were compared to undergraduate freshman and sophomore-level engineering standards. The evaluation by staff at the UTEP Aerospace Center revealed that the complexity and detail of the students' work were on par with early collegiate engineering projects, indicating a significant leap in their understanding and application of engineering principles.

Quantitative data collected from pre- and post-camp assessments showed an average improvement of 85% in test scores, affirming a substantial increase in students' knowledge and skills. Additionally, the quality of the capstone projects, as evaluated by the rubric, underscored the students' capability to produce work with a high level of detail and

creativity that aligns with collegiate standards. These results provide compelling quantitative evidence of the program's effectiveness in enhancing students' understanding and application of engineering concepts in real-world contexts.

Furthermore, 100% of students participated in the optional STEM Student Showcase at the end of the camp, indicating a high level of engagement and interest in showcasing their work. These quantitative measures reflect the program's success in enhancing students' STEM knowledge and enthusiasm for STEM subjects.

3. Shift in students' confidence and attitudes towards STEM education and careers: Post-program surveys indicated that 100% of students felt more confident in their ability to pursue STEM education and careers compared to the pre-assessment survey of just 25%. This shift in attitude is a crucial indicator of the program's success in inspiring students. The program not only improved students' academic understanding but also positively influenced their confidence and aspirations in pursuing STEM education and careers. Before participating in the STEM camp, the students shared a common sentiment of uncertainty regarding their future career paths. One considered seeking employment through a sibling, another admitted to a vague understanding of what engineering entailed, and a third expressed interest in computers and space exploration without knowing how to combine these interests. However, the transformative experience at the STEM camp significantly clarified their aspirations. Post-camp, all three previously undecided students voiced a unanimous desire to join the UTEP Aerospace Center. They were captivated by the prospect of engaging in paid NASA-related research, seeing it as an opportunity to earn while immersing themselves in learning and contributing to space exploration. The concept

of being compensated to expand their knowledge and skills in such an inspiring environment was profoundly appealing to them.

Overall, the program's achievement of recruitment goals, academic success, quantitative improvement in students' understanding and interest in STEM, and the positive shift in students' confidence and attitudes towards STEM education and careers demonstrate its significant impact on students' academic and personal development. These findings highlight the program's success in inspiring and preparing students for future endeavors in STEM fields.

8.4.4 Academic Performance and Skill Development:

1. Improvement in students' STEM knowledge and skills: Analysis of pre-and post-program assessments revealed improvements in students' STEM knowledge and skills. This indicates that the program effectively contributed to enhancing students' academic proficiency in STEM subjects.

2. Development of problem-solving, critical thinking, and teamwork skills: The program's focus on problem-solving, critical thinking, and teamwork was evident in the improvement of these skills among participants. Additionally, the decision of students to participate in the STEM Student Showcase further demonstrates the development of their presentation and communication skills. This reflects the program's success in not only enhancing academic skills but also in fostering important soft skills that are essential for success in STEM fields.

3. Increased interest in pursuing higher education and careers in STEM fields: The success of the program is also reflected in the students' increased interest in pursuing higher education and careers in STEM fields. This demonstrates the program's impact on shaping students' aspirations and motivating them to consider STEM-related career paths.

Overall, the program's contribution to improving students' STEM knowledge and skills, as well as fostering problem-solving, critical thinking, and teamwork abilities, demonstrates its effectiveness. Additionally, inspiring students to pursue higher education and careers in STEM fields highlights its role in promoting academic and personal growth among participants. These findings emphasize the program's success in preparing students for future academic and professional endeavors in STEM fields.

8.4.5 Community and Family Feedback:

1. Positive feedback from families and the community: Feedback from families and the community was overwhelmingly positive. The program was commended by both school administration and parents for its impact on student motivation and for providing opportunities that were previously inaccessible to many participants. 100% of families reported feeling more confident in their understanding of the opportunities and resources available and appreciating the personalized attention and information tailored to their children's aspirations in STEM fields. This indicates that the program not only positively impacted students but also had a broader positive impact on the community.

2. Local news coverage: Several local news articles were written featuring this positive feedback from the community. This demonstrates the program's success in generating interest and support from the broader community and highlights its positive impact on the community.

3. Involvement of families in events: The involvement of families in events like the STEM Student Showcase created a supportive environment for the students and increased community awareness of the importance of STEM education. This indicates that the

program not only engaged students but also fostered a sense of community involvement and support for STEM education.

Overall, the program's positive impact on the community, as evidenced by the overwhelmingly positive feedback from families and the local news coverage, highlights its success in promoting STEM education and fostering community involvement and support. These findings can be used to further enhance the program's community engagement strategies and to promote the importance of STEM education within the broader community.

8.4.6 Long-Term Impact:

1. Academic and career outcomes: The long-term impact of the program is evident in the number of students who expressed interest in continuing their education in STEM fields. Specifically, 3 out of 3 students in 12th grade applied and were accepted to UTEP to study engineering as a direct result of this program. The program's influence extends beyond immediate academic intentions, as evidenced by the enthusiastic decision of our 11th-grade student and their peers, who are now expressing a keen interest in participating in the next summer's program. This collective eagerness not only highlights the individual impact on students' educational trajectories but also underscores the program's broader appeal and effectiveness in cultivating a community of learners eager to deepen their engagement with STEM fields.

2. Recognition and support from external organizations: America Achieves, a national non-profit group, has selected the UTEP Aerospace Center for a grant to further explore the benefits of Education to Employment (E2E) opportunities. This recognition and support from an esteemed national organization confirms the program's impact and potential to contribute to systemic changes in boosting economic opportunity and mobility. It also

highlights the program's alignment with evidence-based practices and its potential to serve as a model for educational initiatives.

Overall, the program's success in facilitating students' academic and career outcomes and its recognition and support from external organizations demonstrate its significant impact and potential to contribute to broader systemic changes in education and workforce development. These findings can be used to further enhance the program's outreach and collaboration with external partners and to leverage its success for broader systemic impact.

8.5 EDUCATIONAL ANALYSIS

The details of the research provide a rich, in-depth exploration of the educational dynamics within the context of targeted STEM education initiatives. The examination of data sought valuable insight into the effectiveness of the interdisciplinary framework in enhancing equity and cultural diversity in STEM education. This approach aligns with the central goal of community empowerment, setting a precedent for an equitable and socially sustainable trajectory that other communities can adopt. As previously stated, implementing steps from the E3 framework is the beginning of a continued and consistent journey and results may take time before tangible evidence can be realized. However, it’s not the number of steps implemented that matter, it’s taking the initial step towards investing in human capital that has the potential to positively change future generations within an underserved community.

8.5.1 Program Outcomes:

Integration of Advanced Technologies: Emphasizing the importance of keeping pace with the rapidly evolving technological landscape, the program integrated advanced technologies into its curriculum. This includes the use of virtual reality for immersive learning experiences, coding software for developing computer programs, and researching advanced simulation tools for

engineering projects. Such exposure to cutting-edge technologies helps prepare students for future academic pursuits and careers in high-tech industries in an age of an emerging digital engineering. As a direct result of the summer camp, the students had the opportunity to attend the 2nd IACM Mechanistic Machine Learning and Digital Engineering for Computational Science Engineering and Technology hosted at UTEP. There, they participated in sessions that deepened their understanding of concepts in digital engineering. This experience not only expanded their knowledge but also further ignited their interest in the engineering field.

Evaluation and Feedback Mechanisms: A critical aspect of the program is its robust evaluation and feedback mechanisms. Regular assessments are conducted to monitor student progress, understand their learning challenges, and tailor teaching methods accordingly. Feedback from students is also actively sought to continuously improve the program's effectiveness and ensure that it meets the needs and expectations of its participants.

Strengthening Higher-Ed Connections: The MAA Southwest program fosters strong connections with EPCC, Western Tech and UTEP. These connections provide students with opportunities to visit the university campus, interact with college students and professors, and observe collegiate-level projects and research. This exposure clarifies the university experience and encourages high school students to aspire to higher education.

Extracurricular and Leadership Opportunities: Recognizing the importance of holistic development, the program includes various extracurricular and leadership opportunities. Students can lead teams in projects, participate in competitions, and engage in community outreach programs. These activities are designed to build leadership skills, confidence, and a sense of community responsibility.

Long-Term Tracking and Support: The program goes beyond immediate educational outcomes by setting up a long-term tracking system. This system follows the progress of participants even after they graduate from high school, offering support and guidance in their college applications and early career choices. Such long-term engagement ensures that the benefits of the program extend into the students' future educational and professional endeavors.

8.6 Limitations and Delimitations

Acknowledging the limitations and delimitations of the study is crucial for contextualizing the research findings and understanding the scope of their applicability. The potential for participant bias in self-reported data is a common limitation in social science research, and in this study, it underscores the importance of critically evaluating the data collected and considering the potential influence of participants' perspectives on the results. Furthermore, conducting research within a specific geographical and cultural context introduces limitations in terms of the generalizability of the findings. The unique characteristics and dynamics of the targeted community may not fully represent the spectrum of experiences and perspectives in other settings, emphasizing the need for cautious interpretation and application of the study's outcomes beyond its specific context.

In addition to the limitations, the delimitations of the study provide essential insights into the boundaries and focus of the research. By concentrating on a single community, the study gains depth and specificity in understanding the needs of the local context; however, it also restricts the broader applicability of the findings to other communities with distinct characteristics.

Moreover, the use of secondary data as a delimitation underscores the reliance on existing information, which may limit the scope of the study's insights and prevent the exploration of real-time or context-specific dynamics. Understanding these delimitations is crucial for interpreting the

study's findings within the context of their specific application and recognizing the constraints that may influence the transferability of the results to other settings.

Overall, by acknowledging both the limitations and delimitations, the study provides a transparent framework for understanding the boundaries, potential biases, and contextual constraints that shape the interpretation and application of its findings. This critical awareness enhances the credibility and relevance of the research, guiding future endeavors in addressing similar issues within diverse contexts while recognizing the specificities and constraints inherent in the study's design and implementation.

8.7 Significance of the Study

This study holds significant importance in the context of social sustainability as it introduces a framework comprising instruction-initiated resource activation, community-centered STEM education, and culturally attuned parent engagement to foster community empowerment. By integrating these components, the study aims to contribute to the social sustainability of Hispanic communities in West Texas. The framework acknowledges the unique cultural context of these communities and seeks to empower them through educational initiatives that are tailored to their specific needs and challenges, aligning with the principles of social sustainability. The emphasis on instruction-initiated resource activation recognizes the importance of leveraging existing strengths and resources within the community to support educational initiatives, thereby promoting social sustainability by building on local assets and knowledge.

Additionally, the focus on community-centered STEM education aims to equip students with the skills and knowledge necessary to succeed in a rapidly advancing technological world, contributing to the social sustainability of the community by preparing its members for the future. Furthermore, the incorporation of culturally attuned parent engagement within the framework

acknowledges the pivotal role families play in shaping students' educational experiences. It aims to bridge the gap between home and school, promoting a more supportive and inclusive learning environment.

This approach aligns with the principles of social sustainability by fostering stronger relationships between families and educators, and by actively engaging and empowering families within Hispanic communities. Overall, the significance of this study through the lens of social sustainability lies in its holistic approach to empowering Hispanic communities in West Texas. By integrating instruction-initiated resource activation, , culturally attuned parent engagement, and community-centered STEM education this study aims to contribute to the social sustainability of these communities by leveraging local resources, preparing students for the future, and fostering inclusive and supportive educational environments. This approach aligns with the principles of social sustainability by promoting equity, inclusivity, and the long-term well-being of the community.

8.8 CONCLUSION:

The comprehensive research design and methodology outlined in this chapter ensure a thorough evaluation of the program's impact. The program has successfully created a pipeline for students, particularly those from underrepresented backgrounds, to enter STEM fields, thereby addressing the broader goal of diversifying the STEM workforce. In conclusion, the MAA Southwest program at UTEP has demonstrated significant effectiveness in engaging and inspiring high school students in STEM, particularly in aerospace-related fields. The positive student feedback, high engagement levels, and quantitative measures of success highlight the program's impact on both individual participants and the wider community.

The MAA Southwest program's contributions go beyond academic achievement; it plays a pivotal role in enhancing educational equity. By targeting underrepresented and economically disadvantaged communities, the program bridges significant gaps in STEM education. This initiative not only opens doors for individual students but also paves the way for a more inclusive and diverse STEM workforce. The success of the program is a testament to the positive outcomes achievable when educational equity is prioritized and actively pursued.

The program's impact extends into the broader community, fostering a culture that values and supports STEM education. Through its various initiatives, the program has nurtured a sense of empowerment among students, parents, and community members. It has highlighted the potential of STEM education as a catalyst for community development and economic growth. This model serves as an inspiration for similar programs across the country, demonstrating how targeted educational initiatives can lead to broader societal benefits.

The MAA Southwest program sets a high benchmark for future STEM education initiatives. Its holistic approach, which combines rigorous academic preparation with personal and professional development opportunities, offers a blueprint for success. The program's ability to adapt to the needs of its participants, coupled with its commitment to continuous improvement based on feedback and evaluation, makes it a model worth emulating. Its success illustrates the importance of commitment, innovation, and community involvement in educational programs, especially those aimed at addressing disparities in STEM education.

Chapter 9: Conclusion

9.1 Introduction

As this dissertation journey reaches its conclusion, the insights gathered mark a significant milestone. These insights have emerged from a comprehensive literature review, the development, implementation and assessment of an interdisciplinary framework, alongside an in-depth case study of the "Elevate to Empower" program. Together, they demonstrate the pivotal role of STEM education in advancing social sustainability and empowering communities. This final chapter synthesizes the core findings, reflects on the theoretical and practical contributions of this research, and outlines avenues for future exploration.

9.2 Synthesis of Key Findings and Practical applications

The integration of STEM education within environmental engineering, as explored through this dissertation, has demonstrated a significant potential to address critical challenges of social sustainability and community empowerment. The interdisciplinary framework presented in Chapter 3 and applied in the "Elevate to Empower" program detailed in Chapter 8, illustrates a viable pathway to not only enhance educational STEM outcomes but also to foster a more inclusive and empowered community. Key findings indicate that targeted, experiential learning opportunities, coupled with community engagement and mentorship, can profoundly impact students' interest, engagement, and achievement in STEM fields.

9.2.1 Impact of the “Elevate to Empower” Case Study

The "Elevate to Empower" case study serves as a testament to the framework's applicability and impact. This initiative not only highlighted the challenges faced by underserved communities but also showcased how strategic educational STEM interventions can assist to minimize these barriers. This initiative highlights the versatility and impact of the E3 framework in a real-world

setting. The program's success in inspiring and preparing students for STEM careers, particularly in engineering, emphasizes the importance of experiential learning, financial and career guidance, and university exposure in STEM education. These insights are invaluable for educators, policymakers, and community leaders seeking to replicate similar STEM programs in diverse contexts.

9.2.2 Instruction-Initiated Resource Activation (I^2RA) Strategy in Action

Incorporating the Instruction-Initiated Resource Activation (I^2RA) strategy, the NASA MAA Camp in El Paso, Texas exemplifies impactful engagement. This initiative, implemented in collaboration with the UTEP Aerospace Center, reaches out to minority groups, including females, by immersing them in aerospace engineering projects aimed at environmental betterment, such as "Sound Damping" activities. Beyond fostering greater STEM involvement among its diverse participants, the camp has equipped them with vital, engineering skills such as improved problem-solving, analytical thinking, creativity and innovation, technical proficiency, and project management. The program's success has led to a partnership with an all-girl STEM school, culminating in the establishment of the first "All-Girl Aerospace STEM Academy". This endeavor further extends the I^2RA component's reach and has led to the proposed implementation of E3's additional components. The program will utilize local resources to improve educational STEM outcomes and address engineering challenges specific to the community. By facilitating mentorship and job shadowing opportunities, through connections with established area engineering companies, the program will support a direct pipeline into STEM careers at the university level and address the gender gap identified in Chapter 2. Moreover, Workforce Solutions Borderplex has communicated an interest to collaborate by offering financial stipends to eligible students. This initiative aims to mitigate the expenses associated with participating in

summer STEM camps, making them more accessible to students in need. These initiatives serve as a testament to the framework's capacity to help empower historically underserved communities through STEM education, embodying the principles of Community-Centered STEM Education.

9.2.3 Leveraging Advanced Technologies: A NASA Director's Initiative

Reflecting on insights shared at the annual NASA Better Together Conference, a director was motivated by the effectiveness of the "Elevate and Empower" program, particularly the strategies implemented in the use of the E3 framework. As a direct result, the NASA director initiated a consultation to discuss integrating STEP 3 from the CCSE component with educators in the NASA Community College Aerospace Scholars (NCAS) program. Therefore, a presentation was organized to demonstrate to this group of educators how integrating advanced technologies into the STEM curriculum can help level the technological playing field for underserved students. This approach not only puts cutting-edge tools directly into their hands but also ensures they stay at the forefront of adopting and implementing these future technologies.

9.2.4 District-Wide Implementation: A Superintendent's Vision

Inspired by the framework's potential, a superintendent from El Paso sought to implement the comprehensive E3 framework across every school in their district, demonstrating its applicability and impact. Following this example, a second district has also adopted the framework, rolling it out in 3 of their high schools. Such widespread interest and adoption underline the transformative potential of the E3 framework, positioning it as a potential cornerstone for future STEM education initiatives aimed at fostering inclusive, impactful, and sustainable learning environments across various underserved communities.

9.3 FUTURE RESEARCH

This interdisciplinary framework sets a foundation for enhancing STEM education within environmental engineering contexts, with implications for social sustainability and community empowerment. Looking forward, several areas present promising avenues for future research:

Comparative Studies: Investigating the framework's applicability and impact across different geographical and socio-economic contexts will provide insights into its adaptability and scalability. Comparative studies can highlight the framework's universal components versus those that require localization.

Longitudinal Impact: Initiating long-term studies to monitor the enduring effects of the framework on communities and STEM education outcomes will be crucial. These studies should focus on tracking career pathways of participants, community sustainability metrics, and ongoing engagement with STEM fields.

Technology Integration: With the rapid advancement of educational technologies, exploring how digital tools and platforms can further support the framework's objectives represents a vital research direction. Specifically, the role of virtual reality and online learning environments in enhancing STEM education warrants in-depth exploration as well as the possible incorporation of artificial intelligence.

Interdisciplinary Curriculum Development: Developing and testing STEM curricula that integrate environmental engineering principles with other disciplines, such as social sciences and arts, could offer new insights into effective interdisciplinary STEM education practices.

Stakeholder Engagement Models: Further research into innovative models for stakeholder engagement could enhance E3’s framework's effectiveness. This includes exploring partnerships

with industry, government, and non-profit organizations to provide real-world learning opportunities and resources.

By addressing these future research directions, subsequent studies can build upon this dissertation's findings, contributing to the continuous improvement of STEM education practices and their role in fostering environmentally sustainable and socially empowered communities.

Looking ahead, several areas warrant further investigation. Comparative studies across different geographic and socio-economic contexts could further refine E3's framework for adaptability and scalability. Longitudinal research is needed to assess the sustained impact of such educational STEM interventions on community empowerment and individual STEM career trajectories. Additionally, exploring the integration of digital technologies, such as artificial intelligence and virtual reality, in community-centered STEM education could unveil new opportunities for engaging and inspiring students.

9.3.1 Opportunities for Research

1. Interdisciplinary Approach to STEM Education: Investigate various components when implementing STEM education in an effort to advance community empowerment and sustainable development. This research will emphasize the importance of experiential learning, community engagement, and mentorship in addressing environmental challenges.
2. Strategies for Increasing Diversity in STEM: Researching effective interventions and educational models that address the underrepresentation of minority groups in STEM. This includes exploring how culturally relevant education and parental engagement can narrow educational and opportunity gaps.
3. Community-Centered STEM Projects: Examining the impact of community-centered STEM education projects on local environmental challenges. This involves studying the

outcomes of projects that leverage local knowledge and address community-specific problems, thereby fostering a problem-solving mindset leading to a contribution towards community empowerment.

4. Sustainable Community Development through STEM Education: Investigating the effects of interdisciplinary STEM education on community development, including its impact on educational and social aspects of the community. This research could serve as a blueprint for sustainable growth and empowerment through STEM education in other underserved communities.

Notably, there exists a deficit of tailored instruments designed to advocate for social sustainability and community empowerment within underserved communities. The creation of such a tool is crucial for fostering sustainable solutions that help to improve economically disadvantaged Hispanic communities, thereby contributing significantly to the overarching aims of social sustainability and community empowerment. To bridge this void, this research proposes the development of an interdisciplinary framework. This framework is meticulously designed to effectively utilize local resources, be socially attuned to parents' needs, and orient STEM education towards addressing the specific needs and challenges of these communities. It offers an innovative, comprehensive strategy aimed at amplifying the impact of STEM education on environmental engineering solutions, marking a pivotal step towards equipping underserved communities with the means to drive their own sustainable development. By addressing these gaps and exploring these research opportunities, this dissertation aims to contribute to the body of knowledge on integrating STEM education as a tool within the field of environmental engineering to help contribute towards social sustainability and community empowerment. This research is particularly relevant for engineering educators, policymakers, and community leaders seeking to

implement similar interdisciplinary frameworks as a tool towards promoting social sustainability and community empowerment in underserved communities.

9.4 Closing Remarks

This work contributes to the academic discourse by bridging gaps in the literature on the intersection of STEM education and environmental engineering. By applying Social Cognitive Theory and principles of constructivism, this dissertation enriches the understanding of how educational frameworks can be designed to be both socially inclusive and academically comprehensive. This research adds a detailed perspective on the role of community-centered approaches in STEM education, offering a model for future curriculum development and educational policy.

In essence, this dissertation presents the transformative power of integrating STEM education with environmental engineering to help create more sustainable, equitable, and empowered communities. As we move forward, it is imperative that we continue to explore, refine, and expand upon these educational models, ensuring that the next generation of engineers is not only technically proficient but also socially conscious and community-oriented. STEM education acts as a catalyst to foster an interdisciplinary collaboration among various engineering disciplines, uniting these engineering expertise to collectively address environmental challenges. This integrated approach enables the development of comprehensive solutions that leverage the strengths and perspectives of each field, ensuring innovative and sustainable outcomes in tackling today's critical environmental issues. Through continued research, collaboration, and innovation, we can aspire to build a future where STEM education serves as a cornerstone of sustainability and empowerment for underserved communities.

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Glossary

CCSE- Community Centered STEM Education

I^{2}RA-Instructor-Initiated Resource Activation

ISD-Independent School District

K-12: Kindergarten through Twelfth Grade

MAA-MUREP Aerospace Academy

MUREEP- Minority University Research and Education Project

NASA-National Aeronautics and Space Administration

P.O.W.E.R.-Preparing Outstanding Women for Engineering Roles

PREP- Parent Resource Engagement Program

STEM- Science, Technology, Engineering, and Math

TEXPREP-Texas Pre-Freshman Engineering Program

UTEP-University of Texas at El Paso

Appendix 1: E3 Framework

Interdisciplinary Framework

Custom Name Idea

E^3 Framework

The **E**co-Engineering **E**ducation for **E**mpowerment **(E3 Framework)** skillfully incorporates the notion of "Eco," referring to ecological or environmental concerns, with "Engineering Education" to emphasize the integration of environmental engineering principles into educational practices. The term "Empowerment" highlights the framework's goal of supporting individuals and communities to take meaningful actions toward sustainability and environmental stewardship. Here's a deeper look at each component of the name:

Eco (Ecological or **Environmental**)

- Eco stands for ecological or environmental, indicating a focus on learning and initiatives that promote understanding and preservation of the natural world. Within this framework, eco-related topics are not just content to be learned; they are integrated into the curriculum in ways that show students the interconnectedness of ecosystems, the impact of human activities on the environment, and the importance of sustainable practices.

Engineering Education

- This part of the name emphasizes the framework's commitment to incorporating engineering principles and practices into the curriculum. It's not just about teaching students the technical aspects of engineering but also about applying these principles to solve real-world environmental challenges. This includes designing sustainable systems, developing technologies to protect natural habitats, and improving human well-being without compromising the earth's ecological balance.

Empowerment

- Empowerment here is twofold: it refers to empowering students with the knowledge and skills to make a difference in the world and empowering communities by involving them in educational initiatives that lead to sustainable development. The framework aims to cultivate a sense of agency among learners, enabling them to become active participants in creating a more sustainable and equitable world.

The E3 Framework is thus a comprehensive educational model that integrates environmental awareness and engineering solutions with the goal of empowerment. It's designed to prepare students not only for careers in STEM fields but also to be environmentally conscious citizens who can apply their knowledge and skills toward addressing ecological challenges and contributing to the sustainability of their communities. This approach fosters a deep understanding of the complex relationship between human society and the natural environment, encouraging a commitment to sustainable living and environmental stewardship.

Appendix 2: Methodological Approach for Each Framework Component

To evaluate the framework's impact, a mixed-methods approach will be employed. According to Prosek's (2019) study, utilizing a mixed-methods approach in program evaluation offers distinct advantages by merging quantitative and qualitative data, thus enhancing the understanding of program outcomes and impacts. This method strengthens the validity of evaluation findings through the cross-verification of data from various sources, ensuring a balanced and accurate assessment. It addresses the diverse information needs of stakeholders, providing a rich and detailed picture that facilitates informed decision-making and program enhancements.

Additionally, the research indicates that integrating different data types allows for a detailed exploration of program dynamics, capturing the complexity of program implementation and effectiveness in various contexts. The mixed-methods approach delivers comprehensive insights that guide actionable improvements, aligning programs more closely with stakeholder needs and expectations, thereby significantly contributing to the strategic development and refinement of programs.

1. Instruction-Initiated Resource Activation (I^2RA)

   Objective: To comprehensively inventory the existing STEM resources present within the school and the surrounding community, thereby establishing a solid foundation for defining and supporting the goals and objectives central to the development of a STEM program.

   Data Collection Methods:

   - Targeted Surveys: Distribute concise surveys to a select group of school staff, students, and immediate community partners to evaluate the current state of STEM resources and identify critical needs.

- Focused Interviews: Arrange discussions with a small number of key stakeholders, such as experienced STEM teachers, local industry experts, and community leaders, to gain in-depth insights into potential resources and avenues for collaboration.

Analytical Techniques:

- Simplified Resource Mapping: Employ basic mapping techniques to outline the locations and types of available STEM resources, emphasizing ease of understanding and practical utility.
- Gap Analysis: Directly compare the identified resources against the defined goals and objectives of the STEM program, pinpointing immediate areas for enhancement or additional resource acquisition.
- Content Analysis: Process qualitative data from interviews and surveys to identify core themes and barriers encountered, focusing on actionable insights that can be realistically implemented.

Implementation Consideration:

- Focused Resource Engagement: Prioritize the engagement and allocation of identified resources based on immediate program needs and the capacity of the two-person team to manage and integrate these resources effectively.
- Streamlined Collaboration Efforts: Develop a practical approach for collaboration that fits the scale of a two-person team, possibly focusing on one or two key partnerships with local businesses or community organizations at a time.
- Flexible and Scalable Planning: Maintain a flexible planning stance that allows for adjustments as the STEM program evolves, ensuring that even with limited personnel,

the approach remains responsive to feedback and new opportunities for resource integration.

2. Culturally Attuned Parent Engagement

   Objective: To engage parents in their children's STEM education through culturally responsive practices, enhancing educational experiences from school to home.

   Data Collection Methods:

   - Focus Groups: Collection of qualitative data with parents from diverse cultural backgrounds to understand their perceptions of STEM education and their roles in their children's learning as well as questionnaires measuring changes in parental involvement in their children's STEM education.
   - Participatory STEM Events: To observe parent-child interactions in STEM activities and gather feedback on the engagement strategies.

   Analytical Techniques:

   - Thematic Analysis: To identify common themes across focus groups regarding parent engagement challenges and preferences.
   - Observational Analysis: For data collected during STEM events, focusing on engagement levels and the effectiveness of culturally attuned materials and activities in enhancing parent-child interaction over STEM topics.

   Implementation Consideration:

   - Develop culturally tailored STEM education materials and STEM events for parents and children.

- Train educators on culturally responsive teaching methods that foster parental involvement such as taking parent work schedules into consideration when planning or translating information sent home.

3. Community-Centered STEM Education

   Objective: To integrate community challenges and solutions into the STEM curriculum, making education relevant and rooted in local context and needs. These methods gauge the effectiveness of community-centered education in fostering a sense of ownership and relevance of STEM education among students and community members.

   Data Collection Methods:

   - Community Surveys: To identify local environmental challenges and interests that can be incorporated into STEM projects.
   - Student Projects and Portfolios: Collecting and analyzing the outcomes of student projects that address community-specific problems.

   Analytical Techniques:

   - Comparative Analysis: To evaluate pre-and post-project surveys of community members' perceptions of STEM education's relevance and impact.
   - Project Evaluation: Using rubrics to assess the quality, innovation, and community relevance of student projects.

   Implementation Consideration:

   - Curriculum development sessions with STEM educators, STEM industry professionals, community leaders, and students to co-design STEM projects that address local issues such as the Congressional App Challenge hosted by the U.S. House of Representatives. In this annual free competition, students from across districts have

the opportunity to participate by developing and submitting their unique apps. This competition is specific to each congressional district across the United States, offering students a platform to showcase their creativity and technical STEM skills.

- Establish a continuous feedback loop with the community to update and refine project-based learning initiatives.

Appendix 3: General Methodological Considerations

Across all components, it's essential to ensure:

- Ethical Considerations: Adhering to ethical guidelines in data collection, especially in surveys and interviews, ensuring confidentiality and informed consent.
- Feedback Mechanisms and Iterative Refinement: Using feedback mechanisms to continuously improve the implementation of each component based on assessment findings. A continuous feedback loop, involving quarterly reviews with all stakeholders, will ensure the framework remains responsive to community needs and educational goals. This iterative process allows for real-time adjustments and enhancements based on direct community input and the latest educational research.
- Cross-Component Analysis: Exploring the interconnections between components to assess their collective impact on enhancing STEM education and community empowerment.

This detailed methodological approach not only provides a blueprint for implementing and assessing the interdisciplinary E3 framework but also ensures that the strategies are grounded in the objectives of each component, tailored to meet the needs of the community, and capable of producing measurable outcomes. Furthermore, the methodological approaches employed can shed light on areas where STEM education may need to be refined or expanded to better support the goals of engineering education. By systematically assessing both the outcomes and processes of STEM education, researchers can identify best practices and potential challenges, offering evidence-based recommendations for educators and policymakers aiming to enhance the role of STEM education in driving environmental engineering solutions.

Appendix 4: Census Data

Race and Hispanic Origin	El Paso County, Texas	Presidio County, Texas	United States
Population estimates, July 1, 2023, (V2023)	NA	NA	334,914,895
PEOPLE			
Race and Hispanic Origin			
White alone, percent	91.2%	92.1%	75.5%
Black or African American alone, percent (a)	4.4%	2.6%	13.6%
American Indian and Alaska Native alone, percent (a)	1.1%	2.0%	1.3%
Asian alone, percent (a)	1.5%	1.9%	6.3%
Native Hawaiian and Other Pacific Islander alone, percent (a)	0.2%	Z	0.3%
Two or More Races, percent	1.6%	1.4%	3.0%
Hispanic or Latino, percent (b)	82.9%	82.9%	19.1%
White alone, not Hispanic or Latino, percent	11.2%	12.7%	58.9%

Note: Taken from *U.S. Census Bureau QuickFacts: El Paso County, Texas*. (2022, July 7). Www.census.gov. Retrieved from https://www.census.gov/quickfacts/fact/table/elpasocountytexas

Education	El Paso County, Texas	Presidio County, Texas	United States
Population estimates, July 1, 2023, (V2023)	NA	NA	334,914,895
PEOPLE			
Education			
High school graduate or higher, percent of persons age 25 years+, 2018-2022	80.0%	61.6%	89.1%
Bachelor's degree or higher, percent of persons age 25 years+, 2018-2022	25.0%	21.2%	34.3%

Note: Taken from *U.S. Census Bureau QuickFacts: El Paso County, Texas*. (2022, July 7). Www.census.gov. Retrieved from https://www.census.gov/quickfacts/fact/table/elpasocountytexas

Income & Poverty	El Paso County, Texas	Presidio County, Texas	United States
Population estimates, July 1, 2023, (V2023)	NA	NA	334,914,895
PEOPLE			
Income & Poverty			
Median household income (in 2022 dollars), 2018-2022	$55,417	$29,012	$75,149
Per capita income in past 12 months (in 2022 dollars), 2018-2022	$26,011	$22,256	$41,261
Persons in poverty, percent	21.0%	23.0%	11.5%

Note: Taken from *U.S. Census Bureau QuickFacts: El Paso County, Texas*. (2022, July 7). Www.census.gov. Retrieved from https://www.census.gov/quickfacts/fact/table/elpasocountytexas

Vita

Raquel Haggerty is an esteemed STEM educator with over two decades of experience, dedicated to elevating STEM education from foundational levels to advanced applications. She holds a Bachelor of Interdisciplinary Studies with a focus on Mathematics and a Master of Education in Curriculum and Instruction in Engineering Education from the University of Texas at El Paso and is set to complete a PhD in Environmental Engineering by Spring 2024, marking another milestone in her illustrious career.

Her achievements include founding the first T-STEM Academy for grades 6-12 in the El Paso area, demonstrating her ability to merge academic theory with practical application and fostering environments that nurture future STEM professionals. Raquel's leadership has also led teams to national recognition in STEM competitions, showcasing her talent for inspiring innovation.

Recognized for her contribution to education, Raquel was named the YISD and Region 19 Texas Teacher of the Year in 2016-2017, further honored by a resolution from the Texas House of Representatives. Her role at the Educate Texas Leadership Summit and her work with the UTEP Aerospace Center underscore her commitment to bridging academic and industry needs, particularly in aerospace and advanced manufacturing curriculum development.

Selected by NASA for the Better Together Conference 2023, her work exemplifies her commitment to aligning educational programs with industry needs. Raquel Haggerty's journey underscores her role as a visionary leader in STEM education, making her an invaluable asset for organizations aiming to advance STEM education policies, practices, and programs.

Contact Information: <haggertyraquel@gmail.com>