UNIVERSITY OF CALIFORNIA,
IRVINE

Promoting Equitable Pathways in Engineering and Career Technical Education

DISSERTATION

Submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in Education

by

Jonathan Lee Montoya

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DEDICATION

To

my wife, Meredith, and my son, Sebastián

"A poet must discover that it's his own story that is true, even if the truth is small indeed."

-Jim Harrison

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ABSTRACT OF THE DISSERTATION

Promoting Equitable Pathways in Engineering and Career Technical Education

By

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Doctor of Philosophy in Education University of California, Irvine, 2023

Professor Mark Warschauer, Chair

My dissertation addresses three studies which ask broadly: What are the predictive metrics of functioning AS-CTE pathways? Can students' perceptions of these pathways be changed? Are these pathways equitable for female students?

In my first study, I take a step toward better understanding the metrics that explain functioning AS-CTE pathways. Through ethnography, I observed that when social mobility was added as a metric of high-quality PBL with AS-CTE in a predictive framework of education success, attendance levels improved.

In my second study, I investigated an opportunity gap (Ladson-Billings, 2013) contributing to students' perceptions that AS-CTE does not lead to advanced STEM degrees. That perception forms a resistance to AS-CTE pathways, hindering efforts to include underrepresented demographics such as women. This study aims to explain to what degree the opportunity gap influences perceptions of obscure high-wage, high-skill careers by youth of an underrepresented demographic.

In my final study, I investigated how AS-CTE pathways present barriers to inclusion through hegemonic masculinity (Connell & Messerschmidt, 2005). Building on the work of (Tarantino et al., 2016), this study employs a feminization of PBL mentor intervention to help

break down the barriers of hegemonic masculinity in secondary STEM-CTE classrooms. Through ethnographic action research (Hartmann et al., 2009), I found evidence that the humanizing of our VDC-PBL intervention allowed for sites of resistance to gender norms.

These studies make three important and timely contributions to the field of AS-CTE and engineering education more broadly. First, I uncover and remediate an ineffective metric of program efficacy, then reveal an opportunity gap which impacts marginalized youth more acutely, and finally I reveal a toxic masculinity within AS-CTE pathways which further impacts those with compounding marginalizations. While uncovering these trends, I offer recommendations to remediate these issues, while also highlighting what is working for these pathways.

POSITIONALITY

I bring a complex and nuanced life history and resulting lens to my ethnographic work in San José, California. I was born in this city and have worked in it as a laborer, youth specialist, secondary instructor, and adjunct instructor at the community college. I grew up and taught near the east hills of San José, a community which has its roots as a farming community for the troops up north in San Francisco. My family is mostly working class, and my grandfather grew up on a farm. Now, my family works in unionized industries like customer service and construction. My father is a retired teamster, and I can still remember being on the picket lines as a child while they fought for living wages. Despite the complex historical relationship of the UFW and the teamsters, many of those striking including my father were inspired by the work of César Chávez, whose childhood home is a historical landmark in San José. I see my work as an extension of the UFW's fights for labor reform and unionization. I am old enough to remember watching the tortillas being made in my local grocery store window while organizers urged us to boycott grapes. This background—my history of physical and familial closeness with San José—enhances my understanding of the region and its educational and workforce pathways, including those in the high-tech industries.

As a world technology capital, the Silicon Valley landscape changes as fast as the new iPhone, which leaves its neighborhoods in an ever-gentrifying flux that creates a fleeting temporality to my ethnographic work. By the time my work is read, the landscape will be dramatically different from the one in which I conducted my research.

Because I grew up in this area and have an intimate understanding of it, I am uniquely positioned to research it. I have tacit knowledge and the ability to gain access, not only to the sites I aim to research but to the relationships which would move my work beyond superficial

interviews to real insider information. These close connections are also grounds for some of my pressing concerns. I worry that although I am originally from the community, my role as a researcher during my ethnographic work will other me from my origins and bar me from the rich discussions I would otherwise have with community members. Further, when my work is published, it will be sure to offend someone, be it community members, administrators, or union leaders. I worry that with my goal of social justice, it is inevitable that I will argue for change which some members of the community do not want to see actualized.

Close relationships with stakeholders are vital to my continued success, yet I recognize the tension among them my research presents. Though community colleges, trade education centers, the academy, labor, industry, and public policy share overlapping interests, much of their existence is a direct result of the very inequities I aim to ameliorate through my research. That said, my ethnographic exit will inevitably be painful. Many industry and union leaders have offered me jobs or have considered my role as adjunct faculty as an actualization of the dream of success in the Silicon Valley. Many of these community partners do not really see or understand the role of ethnographic research in service to them or our community.

INTRODUCTION

Applied STEM Career and Technical Education (AS-CTE) has experienced a resurgence—secondary and postsecondary institutions are flush with federal funding earmarked for CTE. Still, due to scant research they are unsure how to spend it. AS-CTE programs are under researched and outcomes are inconsistent. My dissertation addresses this paucity of research through three studies which ask broadly: What are the predictive metrics of functioning AS-CTE pathways? Can students' perceptions of these pathways be changed? Are these pathways equitable for female students?

I address these questions through a series of three interrelated studies. In my first study, I take a step toward better understanding the metrics that explain functioning AS-CTE pathways. In contributing to Project-Based Learning (PBL) theory, Arantes Do Amaral et al. (2018) found that seven PBL essentials form good learning outcomes; Creghan and Adair-Creghan (2015) showed that a measurable outcome of PBL is higher attendance, after which Plasman et al. (2021), using a case of AS-CTE, framed attendance as a predictor of efficacy. Through ethnography, I observed that when social mobility was added as a metric of high-quality PBL with AS-CTE in a predictive framework of education success, attendance levels improved. The study concluded that using the seven essentials and social mobility as a metric of PBL helps explain the observation of PBL's improved efficacy.

In my second study, I investigate an opportunity gap (Ladson-Billings, 2013) which contributes to students' perceptions that AS-CTE does not lead to advanced STEM degrees. That perception forms a resistance to AS-CTE pathways, hindering efforts to include underrepresented demographics such as women. As a result, these pathways are male-dominated. This study aims to explain to what degree the opportunity gap influences perceptions of obscure

high-wage, high-skill careers by youth of an underrepresented demographic. This study focuses on perceptions of the building industry. The opportunity gap is disrupted when students partake in a Virtual Design and Construction (VDC) PBL curriculum. This study follows a pilot humanities-themed VDC-PBL curriculum. Using a community-based participatory research (CBPR) method, through an ethnographic role, observations were checked against a student perception survey. This study revealed that disrupting the opportunity gap (1) narrows a 'perception' gap, (2) teaches virtual design and construction style collaboration, and (3) allows youth to explore topics in sustainability and environmental justice.

In my final study, I investigate how AS-CTE pathways present barriers to inclusion through hegemonic masculinity (Connell & Messerschmidt, 2005). Building on the work of Tarantino et al. (2016), this study employs a feminization of a PBL mentor intervention to help break down the barriers of hegemonic masculinity in secondary STEM-CTE classrooms. Through ethnographic action research (Hartmann et al., 2009), I found evidence that the humanizing of our VDC-PBL intervention allowed for sites of resistance to gender norms. This study calls for the abandonment of male-dominated curricula and their replacement with programs like our learner-centered intervention informed by Connell and Messerschmidt's (2002) hegemonic masculinity theory.

These studies make three important and timely contributions to the field of AS-CTE and engineering education more broadly. First, I uncover and remediate an ineffective metric of program efficacy. Then, I reveal an opportunity gap which impacts marginalized youth more acutely. Finally, I reveal a toxic masculinity within AS-CTE pathways which further impacts those with compounding marginalizations. While uncovering these trends, I offer

recommendations to remediate these issues, while also highlighting what is working for these pathways.

BACKGROUND – The State of Workforce Education in the U.S.

Workforce Education in Silicon Valley

Although San José, California, lies in the heart of the Silicon Valley, one of the world's wealthiest regions, entire groups of residents are pushed to the margins and prevented from partaking in the fruits of this prosperity. As tech draws the best and brightest from all over the world, so too do technical trades taught in Career Technical Education (CTE). There is a call for highly skilled workers in the San José region to construct the many and massive mixed-use development projects that large corporate campuses require. Despite this need for talent, the construction industry lacks functional and equitable workforce pipelines. Consequently, students find themselves lingering in postsecondary CTE programs, remaining stuck in low-skill jobs and never transitioning to these high-wage careers. An opportunity and perception gap at the secondary level exacerbates this lack of transition. The most marginalized students do not know of or actualize the routes to STEM-CTE high-skill, high-wage careers. Lastly, STEM-CTE pathways, in all their forms, whether CTE, AS-CTE, and STEM CTE, are plagued by a toxic environment where a male-dominated work culture functions to push out those who identify as women (Eisenberg, 2018).

San José, California Career Technical Education

At the secondary education level, Career Technical Education (CTE) is geared towards attracting students in comprehensive high schools to select an industry in which to continue an apprenticeship education. Globally, apprenticeship education developed separately from comprehensive high schools and colleges, beginning with traditions that reach back to pre-

industrial society and taking on a new form after the industrial revolution (Groeger, 2017a). In San José, California, the Career Technical Education that does exist in secondary education is located within comprehensive high schools. The facilities are on school sites and though they attempt to replicate an occupational environment, the students do not go to a workplace (Hansen, 2011). In these programs, separation from the worksite has a long-term effect on the quality of education. Since the trades do not administer them, these programs have not evolved to meet industry skill needs (Hansen, 2011). The comprehensive high schools that administer these programs cultivate an overburdened curriculum culture. Despite robust secondary CTE funding, most vocational training now occurs in postsecondary education, including the for-profit colleges coined 'Lower-ed' (McMillan Cottom, 2018). For-profit colleges exploit the lack of well-articulated CTE pathways, with their own pathway efficacy being null at best (McMillan Cottom, 2018).

Critique of Career Pathways

CTE programs have had many titles and until fairly recently were known as vocational education programs. CTE programs in all their forms have been heavily criticized for targeting Black, Indigenous, and People of Color (BIPOC). The worst of these programs perpetuated social inequities through profiting from the economic surplus created from the exploited labor of marginalized people by tracking and enrolling low-income students and students of color in low-skilled and low-wage occupations, thus reinforcing existing social inequality (Oakes, 1983; Oakes & Guiton, 1995). The tracking of students is well documented and has become more acute since Bowles and Gintis (1976) exposed the stratification of vocational and academic pathways. More recently, these unofficial policies are exposed in Shange's (2019) ethnography, where she

exposes school curricula not fulfilling college entrance high school course requirements known as (A-G requirements). Goodyear-Kaʻōpua (2013) reveals unofficial policies enacted by individual schools and administrators which normalize this tracking. Shange (2019), in conversation with Stein (2004), interrogates California's Master Plan for Higher Education and argues that the severity of poverty follows the students to their state-sanctioned impoverished schools with impoverished curricula. She further interrogates de facto course policies that exclude students' matriculation to university and that instead send students through a pipeline either to prison or vocational education (Shange, 2019; see also Coons, 1960). Goodyear-Kaʻōpua (2013) exposes the constraints of the A-G curriculum. Weaving the work of these scholars together reveals that vocational schools were created to perpetuate the culture of poverty, in which college requirements were enforced as a mechanism of exclusion. Groeger (2017a) corroborates this with her theory of School Facilitated Social Mobility, which reveals that de jure policies have been enacted to perpetuate the enrollment of 'elites' in state-subsidized universities. It appears that the master plan is working exactly how it was designed, as evidenced by the influx of federal funding to perpetuate it.

Despite these unjust realities, many school districts flush with federal funding are attempting to change not the efficacy of pathways, but the perceptions of them—rebranding rather than remaking the pathways to highly skilled labor. This rebranding, both nationally and in the San José region, attempts to attract more diverse students, often the same demographics exploited initially under these programs, such as women and students of color. Rebranding of these programs includes changes in course names and shifts in curricula, including certifications and stackable credentials leading, at best, to two-year colleges. Many BIPOC communities and

activists are aware of the historical roots of these pathways and work to distance their communities from different versions of vocational education.

Workforce pathways and native boarding schools

Settler colonialism—the replacement of a people by a colonizing force—is a reality that many in the CTE field either ignore or are just beginning to acknowledge in the introductions of their lectures. The field gives even less attention to the trauma of the vocational roots of native boarding schools (Pember, 2019), which Indigenous populations still feel today throughout the United States and Canada. Abusive boarding schools were created under the guise of assimilation, and to make matters worse, these schools worked to decrease social mobility for native peoples. Lomawaima and McCarty (2006) highlight what they refer to as Safety Zone Theory (SZT), in which curricula are relegated to service careers, and crafts deemed non-threatening to colonial society. Further, boarding schools worked not only to sublate decimated native populations but also to do so under the premise of surplus labor created through the commodification and fetishization of native bodies. These schools were created to teach skills that would leave native peoples in a perpetual proletariat. These programs were founded and allowed to exist because our nation could not envisage native peoples partaking in the fecundity of their native lands that we so sincerely acknowledge in our paltry land acknowledgments.

New Technology, the Same Exploitation

Vocational institutions have exploited people in the United States (U.S.) for many years. In vocational education, proletarization and external labor are personified in high-tech manufacturing industries where exploited workers labor on or with commodities beyond their financial reach. With the rebranding of high-tech CTE in fields such as cybersecurity, software,

and coding, a new vocational education era begins, one that is looking to exploit high-tech workers (Atanasoski & Vora, 2019). Furthermore, there is a new inclusion of exploited affective labor careers where there is a discontinuity in the wage and labor produced (Varma, 2020). This mismatch in the fungibility of wage and labor prices is personified in the affective toll nurses and other frontline workers face due to the global COVID-19 pandemic.

Opportunity Gap and Perception Gap

At the secondary level, students who are most impacted by compounding marginalizations do not see that the building industry can lead to advanced STEM degrees in high-wage, in-demand trades (Montoya et al., 2020). This lack of educational opportunity for marginalized demographics is what Professor Ladson-Billings (2013) coined as an 'opportunity gap.' Valenzuela (1999) identified the racialized hoarding of resources in which the resources available to students are dramatically decreased throughout their academic journey. Ray (2019) clarified the often opaque schemas with which racialized organizations inequitably allocate resources along racial lines. This opportunity gap and hoarding of resources corroborate Groeger's (2017a) concept of credentialism and her critiques of trade unions. As a result, there is a marked difference in not only the actualization of pathway viability but in the perception that these STEM-CTE pathways can lead to advanced STEM careers such as Civil Engineering.

Engineering is CTE and CTE is STEM

According to the National Academies of Sciences, Engineering, and Medicine (NASEM), the first time students are exposed to engineering concepts is typically in secondary technology education courses (NASEM, 2020). These courses are taught by Career and Technical Education

(CTE) instructors "across a range of technical topics, including engineering" (NASEM, 2020, p. 4). Students develop what Katehi et al. (2009) refer to as engineering habits of mind in these courses and with these instructors. STEM-CTE courses are the beginning of career pathways in STEM fields, including construction management and civil engineering (Katehi et al., 2009). These more 'academic' fields lend themselves to dual enrollment and academic equivalency, where students can earn college credit for work completed either in secondary school or at on-the-job training.

Workforce Academic Equivalency

Academic equivalency in the U.S. is not a well-defined concept; recent efforts have begun to redefine ways to quantify the workforce education system. Academic equivalency is the higher education academy's recognition that work-based learning, credentials, and credits issued by Career Technical Education centers are academically equivalent to those issued by lower academy levels. The European Credit Transfer and Accumulation System (ECTS) was implemented to allow for upward social mobility of apprenticed CTE students by recognizing a career of work-based certifications as qualifications that allowed for matriculation into the high academy. Nosair and Hamdy (2017) applied the ECTS measure of credits to a project-based learning medical program to measure educational workload. In California, a comparable system is in its infancy: regional California Workforce Development Boards are integrating education across educational institutions (board members are appointed by the State Governor). The workforce development board has developed a regional education framework that includes partnership academies (Taylor, 2016). Academic equivalency is gaining more traction in the male-dominated STEM-CTE fields such as Civil and Environmental Engineering.

Hegemonic Masculinity in STEM-CTE Pathways

In STEM-CTE, hegemonic masculinity perpetuates gender hierarchies and functions to exclude women and men from pathways and careers that run counter to accepted gender norms and hierarchies (Carrigan et al., 1985, 2018). Hegemonic masculinity is "the pattern of practice (i.e., things done, not just a set of role expectations or an identity) that allows men's dominance over women to continue" (Connell & Messerschmidt, 2005, p. 832). Hegemonic masculinity is not limited to excluding women from typically masculine careers but also functions to discourage young men from enrolling in traditionally female occupations and pathways such as nursing. In STEM-CTE, the existence and perpetuation of hegemonic masculinity functions to exclude women and what Connell and Messerschmidt (2005) refer to as "subordinated masculinities" or less "dominant" forms of masculinity. In the construction industry, such "subordinated" or less "dominant" masculinities run counter to what the industry views as dominant masculinity, thus requiring men and those perceived as men to position themselves in relation to this form of masculinity which perpetuates the subordination of women to men (Connell & Messerschmidt, 2005, p. 833) and perpetuates gendered division of pathways. This problem is reinforced by a toxic work environment that extends into the workforce pathways, which are the secondary and postsecondary classrooms. Kirton (2017) noted that labor unions are not immune to this issue, both within their ranks and in how they represent the interests of their members. Toxic masculinity is omnipresent in every facet of CTE and in each of my studies.

In this dissertation, I am working on the front lines of the CTE field, where very little research has been done, but there is vast potential to impact students' lives and careers. My research is informed by the historical injustices and tracking of previous iterations of vocational

education. Through this work, I will be rewriting historical injustices and moving the field forward by articulating what a successful program is and can be. I strive to ameliorate these injustices through three studies, in which I first identify and define more accurate metrics for AS-CTE pathway success. Second, I uncover and help to disrupt an opportunity gap and perception gap of CTE building industry pathways. Finally, I identify and work to break down toxic masculinity within STEM-CTE pathways.

LITERATURE REVIEW – Metrics, perceptions, and equity in workforce education

What Metrics are Used to Gauge Efficacy in Workforce Pathways? (Intro to Study 1)

Although Silicon Valley, California, is one of the most technologically advanced regions in the world, entire groups of people are pushed to the margins and prevented from partaking in the fruits of this prosperity. Just as tech draws the best and brightest from all over the world, so too do technical trades taught in the workforce postsecondary Career Technical Education (CTE). There is a call for highly skilled workers in the San José region to construct the many massive mixed-use development projects.

Through ethnography as a postsecondary Applied STEM CTE (AS-CTE) instructor teaching those highly skilled workers—using Project-Based Learning (PBL)—I observed that many students fall short of their goal of social mobility to high-skill, high-wage jobs. These findings necessitate further inquiry and a social mobility metric to address the lack of student matriculation into the highly skilled workforce and further problematize the use of innovative PBL pedagogies as the sole means of fostering social mobility. Innovative PBL pedagogy alone will not provide equitable social mobility. To move our PBL pedagogies to the future, theorists must first acknowledge the larger systems that need to be interrogated and redefine success through more precise metrics, such as a social-mobility metric. This research is a distress call reminding our colleagues that in order to move forward and into the future, PBL practitioners and theorists must acknowledge large systemic barriers to ensure efficacy and to include historically marginalized groups who have largely been left out of the fruits of these pedagogical practices to join us in a future created in part through a PBL-driven equitable education.

Traditionally, technical trades were taught through apprentice programs, which often have trade-union-mentored, on-the-job project-based learning formats. Workforce education has taken many forms, and this research is attuned to the past exploitation and pain caused by non-union vocational education programs that targeted Black, Indigenous, and People of Color (BIPOC). These programs perpetuated social inequities through the economic surplus created from the exploited labor of marginalized people. These are examples of programs that do not provide social mobility. This research is not advocating for this form of vocational education, and this research is not looking to build a discounted 'cheap' labor force.

Problem statement: Current research on PBL and the efficacy of postsecondary workforce programs does not convey their impact on true social mobility. Although highly skilled workers are required to build Silicon Valley, that highly skilled workforce is now scarce. I posit that a lack of observed social mobility is not due to low attendance or inferior pedagogy, but could be due to leaks in the education system.

The purpose of this research is to investigate the postsecondary PBL AS-CTE workforce pathways in Silicon Valley to understand what additional metrics help to explain the functioning pathways. This research is guided by two research questions: (a) What current metrics in literature explain functioning AS-CTE education pathways?; (b) What additional observable metric helps to explain functioning AS-CTE education pathways? Through ethnography, this research uncovers two very different postsecondary PBL pathways and thus a new metric of social mobility is proposed to be added to the framework of efficacious PBL programs.

Review of Postsecondary CTE Success Metrics

Applied STEM Career and Technical Education (AS-CTE) research often frames predictors of vocational education success through metrics like motivation (Lee & Stankov, 2018) and measures success in administrative qualities like leadership (Bartlett et al., 2018). Arantes Do Amaral et al. (2018) found that seven PBL essentials lead to good learning outcomes. Creghan and Adair-Creghan (2015) found that PBL resulted in higher attendance—a predictor of program completion as shown by Plasman et al. (2021). To contribute to PBL theory, this research pulls from underpinning concepts in AS-CTE as guides in the formalization of a framework that demonstrates an improvement in predictive performance for academic success—keeping the attendance contribution metric by Plasman and Gottfried in mind—over that last contributed by Creghan and Adair-Creghan.

Project-Based Learning Strategies That Increase Program Completion and Attendance

Creghan and Adair-Creghan (2015) found that school attendance rates of economically disadvantaged students increased when PBL strategies were used in the classroom. The demographics of the students in these findings were similar to those of the feeder schools and postsecondary schools in Silicon Valley. Both Creghan and Adair-Creghan (2015) and Plasman et al. (2021) found that project-based education resulted in higher attendance (PBL and AS-CTE, respectively). They found that correlation with improved attendance was, therefore, a better predictor of academic success than previous frameworks using metrics such as motivation (Lee & Stankov, 2018). This research takes the Plasman et al. (2021) attendance framework as a point of departure.

Underpinning Concepts in AS-CTE Formalizations

In formalization development, this research pulls from the following concepts: project-based learning, critique of workforce education, and historical views of certification in CTE.

Project-Based Learning in Workforce Education

Silicon Valley CTE courses have undergone a paradigm shift, adopting progressive pedagogies which include PBL strategies. The feeder secondary school (Big Piper High) is classified as an engineering education pathway; however, its classes differ from traditional secondary engineering courses in which students are often "singularly focused on a solution and not an iterative design process" (Hughes & Denson, 2021, p. 6). This pathway's engineering curricula leverage core concepts of Project Based Learning (Arantes Do Amaral et al., 2016; Guerra et al., 2017; Larmer & Mergendoller, 2010). Students chose an 'ill-structured problem' (Walker et al., 2015) and followed the seven PBL essentials originally laid out by Larmer and Mergendoller (2010) and utilized by Arantes Do Amaral et al. (2018). These seven essentials state that the problem should have: (1) a need to know, (2) a driving question, (3) student voice and choice, (4) 21st-century skills, (5) inquiry and innovation, (6) undergo critique and revision, and (7) a public presentation. The authors come from a tradition of workforce virtual design and construction courses where PBL projects are presented publicly to an expert panel (Frank & Fruchter, 2014; Fruchter & Courtier, 2011; Tarantino et al., 2016).

Critique of Workforce Education

Highly skilled labor and its pathways, commonly referred to as CTE or vocational education, are being rebranded to attract more students, especially women and students of color.

The truth is that these pathways need rebranding because of their toxic history. Vocational institutions have exploited people in the United States (U.S.) for many years. The exploitation of indigenous youth is just one of many examples of this victimization (Lomawaima, 1996; Williams & Tracz, 2016). Tyack (1974) set the stage to interrogate the urbanization of education which often disregarded community knowledge to the detriment of those such education was supposed to serve. If, as a community, our goal is truly to fix the issues within workforce pathways, then there must be an acknowledgment of the historical tracking and exploitation of marginalized groups at the hands of these institutions. We must also question the efficacy of vocational education and be careful to fully analyze the current gospel on its outcomes (Grubb & Lazerson, 1982, 2005). Many of these schools were created as a means for proletarization, where workers are left in a sort of caste system. In vocational education, proletarization and external labor are personified in high-tech manufacturing industries where exploited workers labor on or with commodities that are beyond their financial reach. With the rebranding of high-tech CTE in fields such as cybersecurity, software, and coding, a new vocational education era begins: one that is looking to exploit a new proletariat within the umbrella of high-tech workers. Furthermore, there is a new inclusion of exploited affective labor careers (Hardt, 1999) where there is a discontinuity in the wage and the labor produced, such as teaching and nursing, in CTE (Vora, 2015). With the 2020 global COVID-19 pandemic, the affective toll that nurses and other caregivers face is a result of a mismatch in the fungibility of wage and labor prices. These mismatches exist by design and are felt more severely by marginalized workers.

Historical Views of CTE Certifications

The mission of the workforce education system is to develop human capital (Kantor & Tycak, 1982). In the U.S., this mission falls to the community college system: 40 percent of U.S.

undergraduates are educated at a community college (Budd, 2018). Those colleges focus on certifications that categorize workers into different classifications of value. Groeger (2017a) saw that craft employers view education as a metric of human capital value. I am acutely aware of the origins of vocational education and the role of certifications rooted in human capital. While aware of this framing, I do not aim to view this study through the lens of human capital theory as defined by Becker (1962), where he articulates that workers' capital can be summed up by a set of skills which may be improved through education and training. I find it ill-equipped to address the core issues with these pathways. Groeger (2021) problematizes human capital theory with her critique of credentialism, where she questions the actualization of human capital benefits through training and credentials alone. Informed by the underpinning concepts of human capital and credentialism, this research looks for a path forward that I posit will more accurately measure success through social mobility and reentry to the academy of higher education and the workforce.

Using a critical lens to view our CTE history, I entered an ethnography alongside a colleague in the Silicon Valley postsecondary AS-CTE education centers to develop and teach a PBL AS-CTE course. Through these ethnographies, I propose adding social mobility as a success metric of postsecondary AS-CTE pathways. This metric can be measured by post-secondary institutions collecting data on student matriculation into industries or universities aligned with their mission statements.

Opportunity Gap and Student Perceptions of AS-CTE (Intro to Study 2)

This research builds upon the *"Community-scale research-based integrated education experience"* by implementing the educational platform envisioned by Tarantino et al. (2016).

Through a community-based participatory research method (CBPR; Akom, 2011), participants and researchers proposed a project-based learning platform that integrates multiple education institutions horizontally across secondary education institutions and vertically with regional apprentice centers, community colleges, state universities, and research universities. This platform emulates the 5-PBL platform developed and taught at Stanford University for several decades (Fruchter & Lewis, 2003).

The question directing this research is: *"If given an opportunity to learn virtual design and construction through project-based learning, to what degree do underrepresented and/or low-income youth perceive the building industry as a career?"*

This research presents a pilot VDC course developed and implemented in California's Silicon Valley region secondary schools. This research furthers the development of the Montoya et al. (2021) pathway through which students can actualize social mobility through careers in the building industry. Using findings from this research, I worked with colleagues toward inspiring teachers and policymakers to rethink how they prepare youth for future careers. The 'pathway to prosperity' increases student participation in high-skill careers, leading to opportunities to continue to college (Symonds et al., 2011). Disrupting the opportunity gap is an essential step in fostering a career and college readiness culture.

Problem-, Project-, Product-, Process-, People-based learning (5-PBL) in virtual design and construction (VDC) education has shown success in achieving some of these goals at the postsecondary and graduate levels (Fruchter, 1998; Fruchter & Lewis, 2003). The definitions we use of 5-PBL and VDC are as follows:

> *Problem-, Project-, Product-, Process-, People-based Learning (5-PBL) is a process of teaching and learning that focuses on problem based, project organized activities that produce a product for a client. PBL is based on re-*

> *engineered processes that bring people from multiple disciplines together (Fruchter, 1998; Lundell et al., 2022).*
>
> *Virtual design and construction (VDC) is the use of multi-disciplinary performance models of construction projects, including their products (facilities), organizations, and work processes for business objectives (Fischer et al., 2017).*

The relation between PBL and VDC begins with the project-based profession of the engineer, the profession that VDC evolved within. Its focus on a project creates the need to adapt to unexpected issues that often do not have a single correct solution. In PBL, a VDC role provides students with the freedom to explore a domain that has few boundaries. PBL is a form of active learning that moves the center of learning from teachers to students and enables teachers to play a supporting role during the learning process. PBL-VDC creates an environment for learning-by-doing in which students from different backgrounds and expertise apply classroom knowledge to real situations and interact with industry mentors to solve design problems (Fruchter & Lewis, 2003).

Despite the general excitement about project-based learning and evidence of its benefits, Ladson-Billings (2013), pushing back on the infamous Coleman et al. (1966) report, which named achievement gaps between Black and white students, identified a discrepancy she coined as the 'opportunity gap' that limits the adoption of high-impact curricula in many schools, including those identified as low-income. This perception forms a resistance to industry entrance via pathways such as apprentice programs (Groeger, 2017b).

> *If underrepresented secondary education students formally learn about building energy efficiency and sustainability in a classroom setting paired with hands-on industry-sponsored experience, then these students can (1) study advanced undergraduate and graduate material, (2) become environmentally conscious members of the building industry workforce, and (3) help improve their community's environmental justice (Tarantino et al., 2016).*

Workforce Development Topography

At the secondary education level in the Silicon Valley, Career Technical Education (CTE) is geared towards attracting students in comprehensive high schools to select an industry in which to continue an apprenticeship education. Globally, apprenticed education developed separately from comprehensive high schools and colleges, beginning with traditions that reach back to pre-industrial society but took on a new form after the industrial revolution (Groeger, 2017b).

Environmental justice curriculum

One concern of the CBPR partners was to include humanities education in STEM through PBL-VDC. There is a widespread movement in education to include environmental justice through PBL education "so that young people can lead informed, meaningful, and transformative lives" (Benavot, 2014, p. 5). Students who have the opportunity to take PBL courses in VDC discover that entering the building industry can lead to advanced STEM degrees in high-wage, in-demand trades (Montoya et al., 2020). However, students who are not offered these courses or what Ladson-Billings (1995) calls good teaching do not believe that advancement is possible. This lack of educational opportunity is what Ladson-Billings (2013) coined as an 'opportunity gap'.

Critical perspectives and curricula such as ethnic studies have shown long-term positive impacts on student success in the San Francisco Bay Area (Bonilla et al., 2021). Valenzuela (1999) identified the racialized hoarding of resources where students' resources are dramatically decreased throughout their academic journey. Ray (2019) made transparent the often opaque schemas with which racialized organizations inequitably allocate resources along racialized

lines. In this platform, the PBL topic focused on regional challenges such as poverty and inequity as well as environmental and social insecurities (Benavot, 2014). Environmental justice issues are real for students in the communities where the course was administered, as environmental stresses and contaminants have measurable community health impacts (Akom, 2011; Gee & Payne-Sturges, 2004; Martinez, 2017; Massey, 2004). The inclusion of environmental justice as a topic specifically for those students most affected by these challenges in an otherwise affluent region is novel.

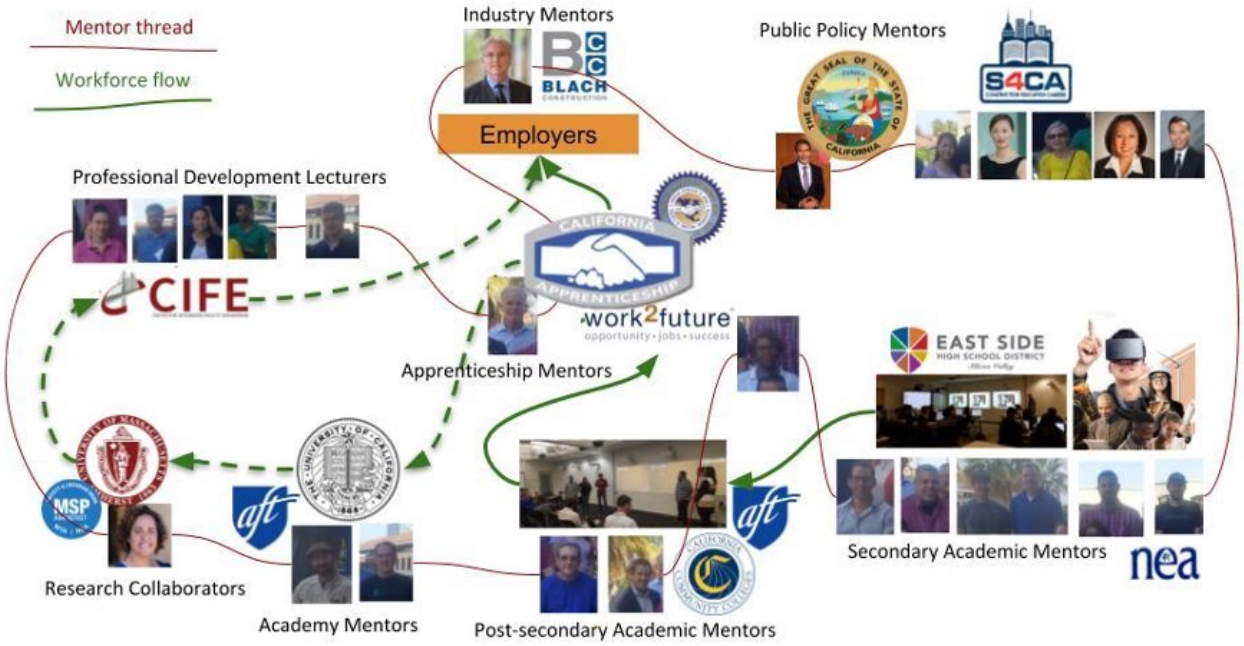
Challenging students' perception of their relationship to their environment leads to students taking ownership of and becoming advocates for their neighborhoods (Nazar et al., 2019). Teaching students VDC methods and opening up their mindset cultivates fertile ground for conceptualizing a better built and more natural environment. "[VDC Methods] improve project and business performance" (Kunz & Fischer, 2020, p. 355). This PBL platform transforms students' perception not only of their career options but also of their self-worth and roles as future leaders in the building industry. When the seeds of social change take hold, these youth, equipped with a new mindset, will be ready to take ownership as protectors of their environment. "Once social change begins, it cannot be reversed. You cannot uneducate the person" (Chávez, 1984, November 9). As this mindset of critical awareness grows, students and teachers begin to understand that "history is a time filled with possibility…that the future is problematic [but] not already decided fatalistically" (Freire, 2000, p. 11). Rather than solidifying societal inequities, education becomes a vehicle for liberation.

This research presents a pilot aimed at supporting a community of educators looking at shaping perceptions of pathways to prosperity (Symonds et al., 2011). It is a formative assessment to determine the performance of PBL in VDC with youth from underrepresented and

low-income backgrounds. This work is concerned with how these youth perceive the building industry as a potential career. I worked with researchers and interlocutors from the community (Figure 1) to implement an opportunity-gap-disrupting educational platform through collaboration with community-based participatory research (CBPR) and measured the efficacy of that platform through ethnography, student perception surveys, and peer review.

Figure 1

Research-Practice Partnership Network.



Note. An evolving network of community participants, researchers, and practitioners (adapted from Montoya et al., 2020; Tarantino et al., 2016). The participants represent each stop in the workforce pathway from education, to employment, to public policy, to labor standards oversight.

Project-Based Learning and Workforce CTE

There is insufficient research on the role of project-based learning in working-class secondary schools to draw conclusions as to its efficacy (Leggett & Harrington, 2021). A large project in the Eastern United States has introduced PBL in working-class communities through Inclusive STEM High Schools, but there is still insufficient research to draw clear conclusions (Noble et al., 2020). Hughes and Denson (2021) have highlighted the lack of interaction, which is a crucial component of effective PBL and engineering education. Underrepresented youth have a difficult pathway in CTE education, and the path that contains VDC—engineering and industrial technology—is one of the most difficult: "Underrepresented students are enrolling at a higher rate than expected in CTE pathways that have a low number of students reaching transfer readiness" (Wolzinger & O'Lawrence, 2018, p. 6).

Silicon Valley, California Career Technical Education

In Silicon Valley, California, the Career Technical Education that does exist in secondary education is located within comprehensive high schools which offer various courses including college preparation. Purely vocational schools and remedial secondary schools are in the minority and not part of this study. The facilities in comprehensive high schools are on the school sites and attempt to replicate an occupational environment, but the students do not go to a workplace (Hansen, 2011). In these programs, separation from the worksite has a long-term impact on the quality of education. Since they are not administered by the trades, these programs have not evolved to meet industry skill needs (Hansen, 2011). The comprehensive high schools that administer these programs cultivate an overburdened curriculum culture that perceives an education for sustainable development as a distraction from the prioritized exam topics. This over-emphasis on exam topics creates a false binary between "hand work" and "brain work," as

if work with the hands cannot demand creativity, critical problem solving, and intellectual rigor. Ultimately, this dichotomy not only limits what kind of work we create in the future, but also "reinforces social separations and cripples our ability to talk across current cultural divides" (Rose, 2014, p. 86).

Despite robust secondary CTE funding, most vocational training now occurs in postsecondary education, including the for-profit colleges coined Lower-ed (McMillan Cottom, 2018). McMillan Cottom (2018) exposed the predatory nature of the institutions that exploit this shift of vocational education to the margins of the academy. These institutions have documented negative impacts on their students with their benefits being null at best (McMillan Cottom, 2018).

There are California State agencies and non-profit organizations that fund, advocate for, or implement Career Technical Education. For example, the state-funded organization California Partnership Academies (CPA) includes fifteen academies specific to the building trades. Those in the region of this study are Big Piper's construction technology academy, a part of the Union High School District, and Salinas' Sustainable Design and Construction (SDC) Academy in Monterey County. These partnership academies work with regional workforce development boards appointed by the California Governor. There are two boards in the study region: the North Valley Job Training Consortium (NOVA) and the San José-Silicon Valley Work2Future.

A Learner-Centered Intervention for a More Equitable Pathway (Intro to Study 3)

The construction industry is plagued by a toxic work environment where a male-dominated work culture functions to push out women (Eisenberg, 2018). More broadly, the hegemonic masculinity (Connell & Messerschmidt, 2005) of traditional construction engineering and STEM-CTE pathways and curricula are of particular concern. This research calls for the abandonment of male-dominated curricula and for their replacement with programs like our learner-centered intervention that is informed by Connell and Messerschmidt's (2002) hegemonic masculinity theory. This research suggests that all workers, and the industry as a whole, stand to benefit from this modification. Further, the well-documented gender pay gaps present across all industries (Blau & Kahn, 2017) are being addressed in the construction industry (McElhaney & Smith, 2017).

Although the narrowing wage gap indicates progress towards gender parity in construction, many women are left out of this promising industry. Science, Technology, Engineering, and Mathematics (STEM) and STEM-Career Technical Education (CTE) courses have been shown to be a pathway into both the construction industry and advanced STEM careers such as civil and environmental engineering (Montoya et al., 2020). However, there is a dearth of female participation in these pathways (NASEM, 2020). Hegemonic masculinity in STEM careers and STEM-CTE pathways prevents young women from entering these traditionally male-dominated sectors (Bonilla, 2020). The third study of this dissertation investigates a learner-centered intervention with aims to break down these barriers through a unique CTE experience. As a team of educators and researchers, we were able to co-create a learner-centered environment using Project-Based Learning (PBL; Fruchter & Lewis, 2003) and an enduring Research-Practice Partnership (RPP; Ahn et al., 2019; Gutiérrez & Penuel, 2014).

The researcher-practitioners intentionally employed Virtual Design and Construction (VDC; Kunz & Fischer, 2020) to disrupt the traditional power dynamics in the classroom. In VDC, students learn through group projects and interactions with a variety of construction industry actors. Through ethnographic action research (Hartmann et al., 2009), the impact of a learner-centered CTE experience was documented. The learner-centered program design allowed a team of researchers and community partners to curate and contribute to a humanizing curriculum (Camangian & Cariaga, 2021) focused on an equitable pathway that, at its very essence, worked to tear down the barriers of hegemonic masculinity and their resulting opportunity gaps (Ladson-Billings, 2013) in STEM-CTE courses.

Hegemonic Masculinity as a Critical Lens to View STEM-CTE Pathways

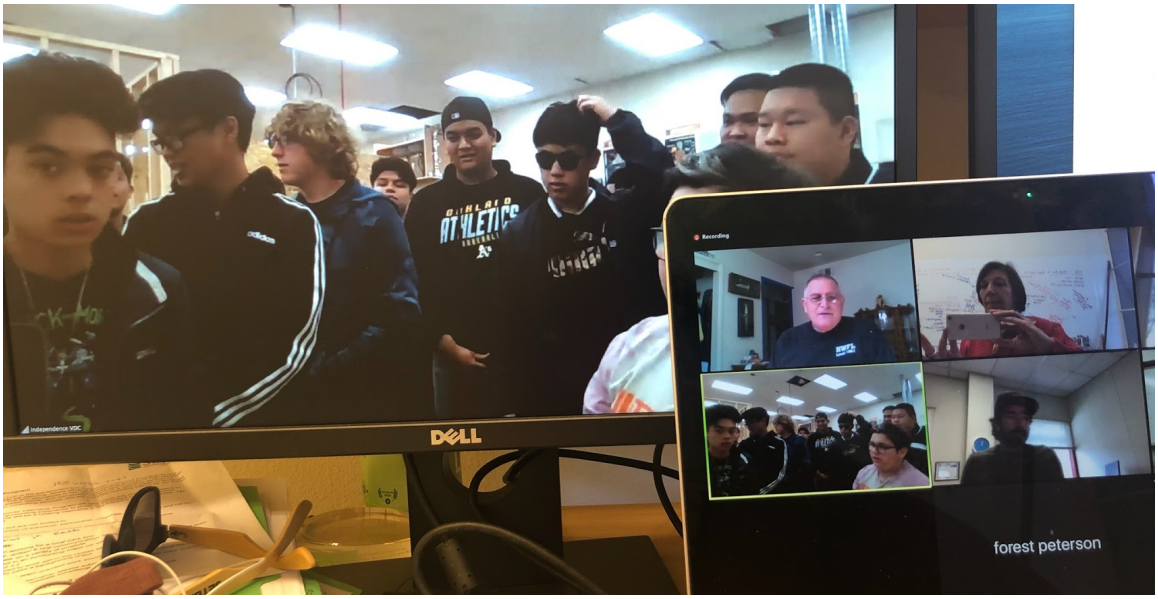
Formalizing the intervention relies on Connell and Messerschmidt's (2002) theory of hegemonic masculinity as a guide and a lens to interpret the data. Hegemonic masculinity is a theory used to describe the hierarchy of masculinities in society. Raewyn Connell first noted this hierarchy in field notes from observations of secondary school students in Australia (Carrigan et al., 1985). In STEM-CTE, hegemonic masculinity perpetuates gender hierarchies and functions to exclude both women and men from pathways and careers that run counter to gender norms and hierarchies (Carrigan et al., 1985, 2018). Hegemonic masculinity is "the pattern of practice (i.e., things done, not just a set of role expectations or an identity) that allows men's dominance over women to continue" (Connell & Messerschmidt, 2005, p. 832). This is not limited to excluding women from typically masculine careers, but also functions to discourage young men from pursuing traditionally female occupations and pathways such as nursing. In STEM-CTE the existence and perpetuation of hegemonic masculinity functions to exclude women and what Connell and Messerschmidt (2005) refer to as "subordinated masculinities," or less 'dominant'

forms of masculinity. In the construction industry such "subordinated" masculinities run counter to what the industry views as dominant masculinity. Social pressures require men to position themselves in relation to this dominant form of masculinity which perpetuates the subordination of women to men (Connell & Messerschmidt, 2005, p. 833) and perpetuates gendered pathways. This problem is reinforced by a toxic work environment that extends into the workforce pathways, which in this case are secondary and postsecondary classrooms. Kirton (2017) noted that labor unions are not immune to this issue, both within their ranks and in how they represent the interests of their members. Unions need to dismantle hegemonic masculinities and gender hierarchies, and this need extends to STEM-CTE courses and pathways, which is the scope of the intervention.

Through ethnography in the industry, we observed low numbers of women working in STEM fields. These low numbers were present both in the building industry itself and in the pipeline courses which function as the predominant feeders to this industry. Much of the existing research sheds light on the toxic work environment that contributes to this gender disparity in the building industry, which extends into secondary and post-secondary classrooms by way of gendered education pathways (Montoya et al., 2020). Due to such low numbers of women, during this study we inadvertently found ourselves directly teaching a significant percentage of the women in CTE construction career pathway courses in the Silicon Valley of Northern California: in secondary CTE women represent only around three percent of students (Hegewisch & O'Farrell, 2015). In a typical high school CTE course, we would expect to see two or fewer women per class. In Figure 2, the predominance of male students is evident, and in Figure 3 the predominance of male teachers is evident.

Figure 2

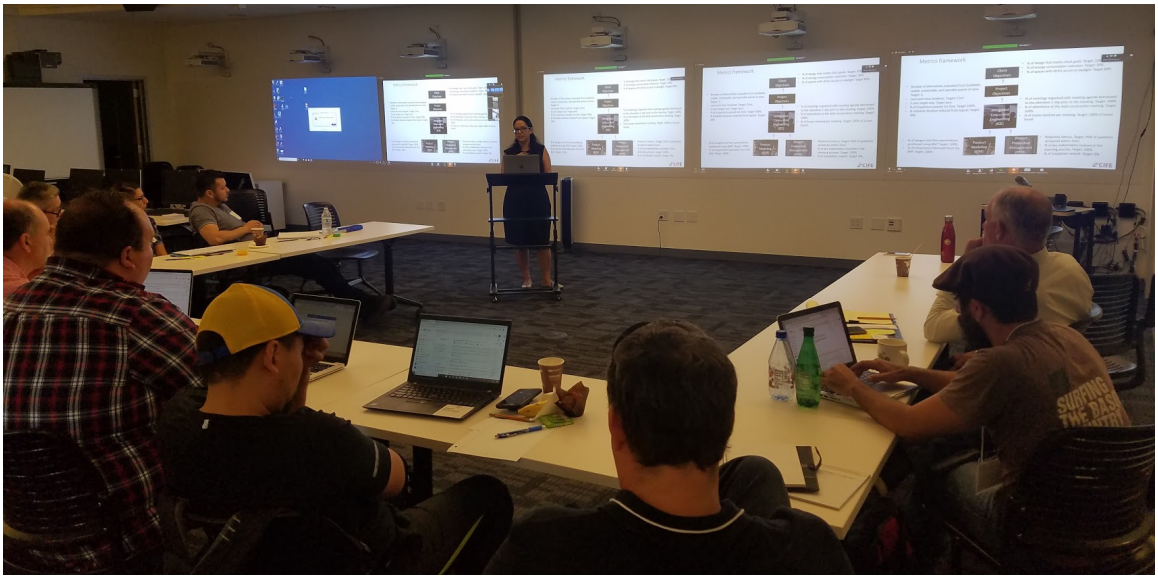
Team check-in: Virtual Design and Construction Secondary Students Prepare to Present



Note. Typical secondary construction program with a predominantly male cohort. Screenshot Montoya

Figure 3

Teacher Summer Professional Development at the Center for Integrated Facility Engineering



Note. The teaching cohort is predominantly male; the only woman is the doctoral student lecturing. Photo Montoya

Over time, women are pushed out of the trades by hegemonic masculinity-based occupational segregation. This baseline topography is the reality for women throughout the world and is not to women's benefit (Anker, 1997). Exclusion based on hegemonic masculinity often relies on unfounded or irrelevant claims, such as a woman's responsibility to family. Anker provides a solution by calling for policies that reduce family responsibilities, remove gender stereotypes, and increase educational opportunities. Even then, there is a purposeful side to occupational segregation through employers finding ways around policy solutions: for example, women are still shorted on work hours (Wright, 2019). Despite the limitations of policy, there is a need for this first step. Without policy protections, low-wage women are particularly vulnerable to segregation (Gleeson et al., 2014). Pockets of exception can be found in India, where a local pattern of female strength differs from the global narrative of perceived weakness. These exceptions further complicate the narrative of women and hegemonic masculinity (Russo, 2018).

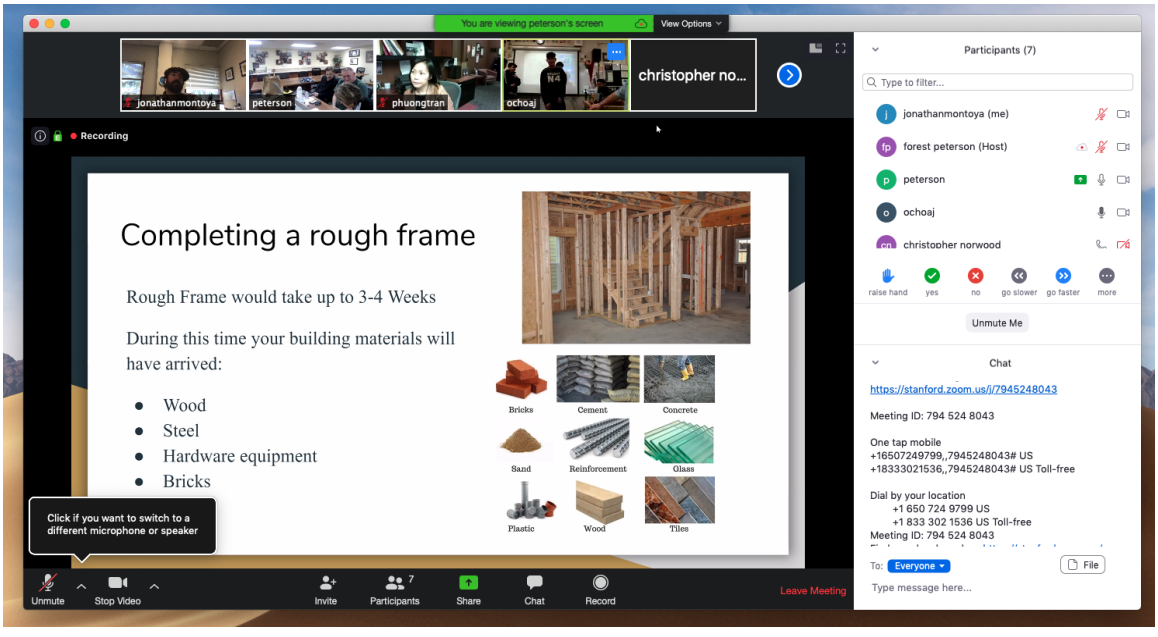
Social Circumstance

Gendered career pathways are thought to originate from social norms whereby children follow in the careers and footsteps of their parents. Kniveton (2004) examines the social circumstances that help to exclude women from this industry and identifies that "the greatest influence on students' choice of career was their parents, followed by that of their teachers" (p. 9). Furthermore, in England—where Kniveton collected data—peerage is a factor: firstborn students' careers were heavily aligned with their parents' while those of younger children were influenced more by their older peers. This follows Willis' seminal ethnography, Learning to Labor, which was also situated in England, where the 'lads' who were the subject of the ethnography followed the lead of their parents and peers (Willis, 1977). The amount that peerage influences career choices in San José is not clear; however, we are aware of the possibility

through (Plasman et al., 2020) and (Plasman & Gottfried, 2020). The research in England added a layer of depth to their conclusions by identifying that their findings may be a result of "the limitations of the power of unions, and the virtual elimination of apprenticeships" (Kniveton, 2004, p. 10). The role of unions and apprenticeship education is at play in San José, and the idea that unions can replace the influence of peerage is an interesting note, as Bol and Weeden (2014) show that there are regional variations to the influence of unions and apprenticeship education. However, those authors did not feature the contribution of peerage nor following of footsteps (Morgan et al., 2013). In Figure 4, you see the typical social circumstance of the young male and the easily prompted interest they intuitively have in associating a construction activity to construction materials–likely a result of social circumstance in a blue-collar community.

Figure 4

Project Critique: Virtual Design and Construction Secondary Students Present Virtually



Note. An example of the virtual call format with a mentor panel of practitioners pulled from the collaborating community of practitioners and S4CA. Screenshot Montoya

With limited apprenticeship opportunities and dwindling union influence, Vuolo et al. (2013) explored pathways from school to work. They examined the role of features to distinguish youth who establish themselves in careers and those who flounder. The features they focused on were adolescent achievement orientations, experiences in school and work, and socioeconomic background. They found that reduced 'floundering' was predicted by factors of academic orientation, socioeconomic background, and steadily paid work during high school. Unionism and apprenticeships—which provide paid, steady work—previously played a greater role within North America in the pathways from school to work but are now both on the decline.

However, declining unionism will not hurt women's representation. Women's representation has been low in male-dominated sectors both with and without union membership. Despite this fact, there is nearly no participation from women in the non-union construction workforce, which does exist, though minimally, in the union workplace. There could be a prevalence of 'leaky' pathways—an important concept to explore in determining whether a lack of information is part of the problem. Do women know about the pathways but attrit because of the cultural and social expectations, or do they not know about these opportunities in the first place? Intuition posits that knowledge of opportunity is not the problem—the typical young man knows nothing about construction industry careers and seems to find a way into these occupations regardless. Taking a logic test, we could ask whether women are missing from chief executive officer (CEO) roles because they do not know they can be CEOs. Clearly this is not the case and there is more at play. Women leaving male-dominated occupations is the leaky pipeline (Frome et al., 2006; NCES, 1997; Oakes, 1983). This leak is repeatedly found in studies that examine gendered occupational aspirations in traditionally male-dominated fields. Frome et al. (2006) studied 104 18-year-olds who were surveyed twice, at 18 (1990) and then at 25 (1997). The

young women in the study who initially aspired to male-dominated occupations lost these aspirations if they also desired a family-flexible job, which gender research shows is a common desire for working women (Anderson et al., 2017).

Idealized Feminist Education

Based on the factors preventing women's participation in the construction field, we developed a multifaceted educational model to promote female participation and success through an idealized feminist education. Project-based learning (PBL) and learner-centered approaches can address an idealized feminist education that uses PBL as a response to the hegemonic masculine culture and history of gendered pathways. Tarantino et al. (2016) envisioned a pedagogical framework that was set in motion in 2018 (Montoya et al., 2018) within the authors' implemented VDC-themed STEM skills course. The VDC course follows a template inspired by the Stanford 5-PBL format in the "Architecture-Engineering-Construction (AEC) Global Teamwork" course (Fruchter & Lewis, 2003). The course we developed on PBL-VDC is based on the AEC Global Teamwork's mentoring education format. For example, during each virtual call, mentors review a team's work and then provide instruction on technical skills related to VDC theory (Kunz & Fischer, 2012) that the mentor would like to see implemented before the next mentoring session. Through this interactive mentoring, students become aware of what it means to have a particular profession (Fruchter & Lewis, 2003). This strategy aims to center the student through the activity between mentors and mentees during mentor sessions. Mentoring occurs both in-person and through Innovative Collaboration Technologies (ICT) (Fruchter et al., 2007). Through ICT, like the Architecture-Engineering-Construction (AEC) Global Teamwork course, the PBL-VDC course scales to an international and cross-disciplinary network of students and mentors in multiple "social worlds."

Idealized feminist education could address gender equity and academic equivalency through a feminization of construction workforce education. To achieve that, we looked to a joint collaboration of contractors and unions. We chose to focus on union apprenticeships because a recent study showed that contractor-led apprenticeship programs that did not work with a labor union had an exceptionally low graduation rate (Illinois Economic Policy Institute, 2020). Further, there are indications that unionized workforce education programs in Europe do well with regard to gender equity and academic equivalency (Hansen, 2011). There are strong examples of success through collaboration: contractors and unions working together have addressed the widespread hazards that cause work-related injuries to construction workers better than each group could individually (Boatman et al., 2015). Using theory from Fruchter's PBL Lab at the Stanford University School of Engineering, the workforce VDC framework aimed to directly disrupt the current trend of excluding young women through its key component of mentorship. The authors looked to form relationships that tie together labor education, leadership development, and movement building for women, through collaboration along with these relationships and by providing labor education through a social justice curriculum (Twarog et al., 2016) (see in Figure 5 a PBL-VDC cohort of young women speaking with an international engineering doctoral student).

Figure 5

All Female Breakout Group at the Center for Integrated Facility Engineering

Note. This cohort of young women gathers around an international Stanford construction engineering doctoral student to share insights into being women in the construction industry. Photo Montoya

Engineering is CTE and CTE is STEM

According to the National Academies of Sciences, Engineering, and Medicine (NASEM), the first time students are exposed to engineering concepts is typically in secondary technology education courses (NASEM, 2020). These courses are taught by Career and Technical Education (CTE) instructors "across a range of technical topics, including engineering" (NASEM, 2020, p. 4). In these courses and with these instructors, students develop what Katehi et al. (2009) refer to as engineering habits of mind. STEM-CTE courses are the beginning of career pathways in STEM fields including construction management and civil engineering (Katehi et al., 2009).

Workforce Education Model

Our workforce education model is grounded in a career pathway model (i.e., stackable credentials in multi-course sequences) and relies on a project-based learning curriculum that we deliver in a feminist learner-centered environment with a social justice focus throughout. The

career pathway approach allows students to earn industry-recognized credentials, beginning in high school, that build upon each other and can be continued in a two or four-year apprenticeship program, and into graduate education.The project-based learning curriculum builds on two established and well-known models for teaching engineering, construction, and sustainable design. Our novel approach includes the intentional recruitment of women as mentors and young women as learner-participants. We ground the curriculum in social justice principles by allowing the learner-participants to identify problems and develop a response with structured support from the mentors and instructors.

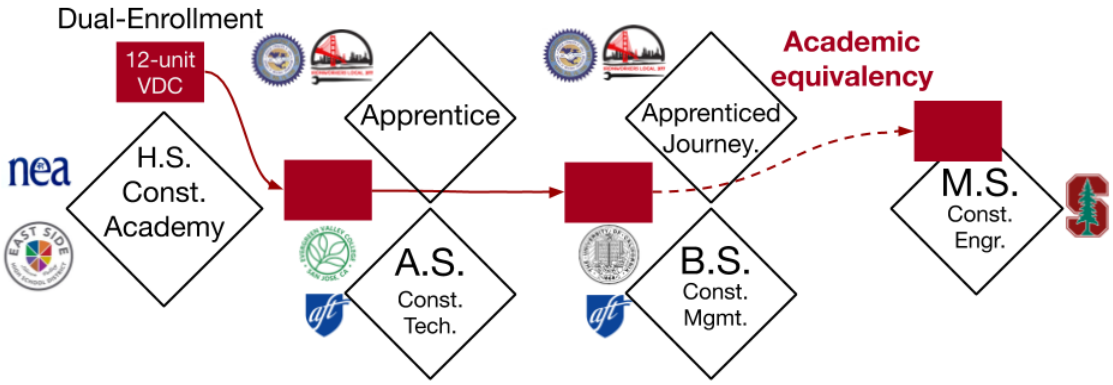
Career Pathway Approach

Historically, CTE programs were called vocational education programs, and have been criticized for separating students into vocational and academic pathways known as tracking and enrolling low-income students and students of color in low-skilled and low-wage occupations and reinforcing existing social inequality (Oakes, 1983; Oakes & Guiton, 1995). Our program intentionally incorporates a carefully designed pathway that instead promotes participant advancement in the STEM-construction fields. In operation, the Workforce VDC program contains three overlapping programs for educators, secondary students, and postsecondary students. Specifically, there is a twelve-month program for educators, a nine-month program for secondary students, and a five-month program for postsecondary students (Montoya et al., 2018). The multi-year curriculum aims to increase participants' engineering and trade skills through a pathway model which consists of specific units that students pass through to earn industry-recognized credentials. The pathway model begins with secondary students, continues through initial apprenticeship programs and post-apprenticeship education, with the potential to complete postsecondary degrees (i.e., certificates, associate's degrees, and bachelor's degrees) and

continue to postgraduate education. In Figure 6, we illustrate the multi-sequential pathway that participants can access and the education and trade unions that participate in the offerings. Students are able to earn industry-recognized credentials (e.g., Workforce VDC Certificate, Stanford continuing education units, and dual enrollment college credits) that allow them to exit the pathway with employable skills at any stage and also to re-enter the pathway at a different location or a later time to help them advance in their careers. In operation, the Workforce VDC program contains three overlapping programs for educators, secondary students, and postsecondary students. Specifically, there is a twelve-month program for educators, a nine-month program for secondary students, and a five-month program for postsecondary students. In this study, we focus on the programming for secondary students.

Figure 6

Pathways from secondary to post-secondary education



Note. Comparable college pathways through trades and traditional college preparatory. (Montoya et al., 2020)

Project-Based Learning Curriculum

Our education curriculum merges curricula from Dr. Reanate Fruchter's PBL Lab with Virtual Design and Construction (VDC) curricula (Kunz & Fischer, 2020). For our CTE high school-aged participants, we incorporated the PBL Lab, virtual format, and milestones, and the pacing of the VDC program (Tarantino et al., 2016). As such, we named our hybrid model Workforce VDC. The trade skills component is typical of CTE programming; however, in our program, mastery of technical skills is taught alongside academic curricula. Many participants received articulated dual-enrollment college credits from these academic curricula, facilitating their progress in postsecondary STEM degree programs. Given the aforementioned history of exploitation that targeted students from lower-income and marginalized racial and ethnic groups, we intentionally incorporate principles of social justice into this academic side of our STEM-CTE pedagogy.

Intervention Pedagogy

Mentor interactions are integral to the program's aim to "foster opportunities for students to interpret and discuss relevant actions that might lead to transformative change" (Camangian, 2015, p. 432). We bring a sense of belonging as well as prestige to students through our implementation of STEM-CTE (Plasman et al., 2021), and our students rise to their potential in their academic performance and community actualization. Actualization is achieved through the disruption and reframing of traditional college and career pathways. The social justice theme developed in the program's second year (Montoya et al., 2018) continues into its current iteration. This project-based learning (PBL) course was first envisioned by Tarantino et al. (2016) and then set in motion by Montoya et al. (2018) within a VDC-themed STEM skills course. Our VDC

course follows a template inspired by the Stanford PBL format (Fruchter & Lewis, 2003). This intervention course follows a mentoring education format with virtual calls, in which mentors review a team's work and then provide instruction on technical skills related to VDC theory (Kunz & Fischer, 2012). Mentoring occurs both in-person and through Innovative Collaboration Technologies (ICT; Fruchter et al., 2007). We created a learner-centered environment through the thoughtful and intentional recruitment of mentors. Following findings by Dee (2007) that same-gendered student-teacher pairings improved student engagement and learning, we recruited many women mentors in close partnership with Meg Vassey and Tradeswomen Inc.

Study One – Social Mobility in Workforce Education

Research Questions

1. What current metrics in literature explain functioning AS-CTE education pathways?
2. What additional observable metric helps to explain functioning AS-CTE education pathways?

Methods

Participants

The study draws on data from students, instructors, and mentors. These participants come from two community colleges that we have collectively given the pseudonym Fiddlers Green College and an adult education center we call the Pipe Trades Education Center. The participants are from the tenth-largest city in the United States. This region's demographics are evenly divided between Latinx, Asian, and white: half of the homes in this city speak English as a second language.

The students reside in a lower-income working-class community whose feeder secondary schools are composed of 50 percent of students who qualify for free and reduced-price meals. The region is industrial, and its working communities suffer from a legacy of contaminants from industrial sites (Montoya et al., 2018; Pimentel, 2004; Schlanger, 2017; Stewart et al., 2014). Despite the racialized socially and environmentally unjust reality, the students are a high-performing and distinctly working-class demographic.

Setting

This study is part of a larger project (Montoya et al., 2018, 2020; Tarantino et al., 2016) which relies on the same Northern California Silicon Valley-based Research-Practice Partnership

(RPP; Figure 1). Our RPP includes educators and other community participants (i.e., union leadership, policymakers, and business partners). Numerous organizations make up our RPP and together are known as the Santa Clara County Construction Careers Association (S4CA). Our larger partnership includes four high schools, three community colleges (i.e., 2-year colleges), eight apprenticeship programs, an adult education program, and two universities (i.e., graduate and bachelor's degree–granting institutions). This study focuses on the postsecondary education institutions.

Social mobility was interrogated through ethnography (Hartmann et al., 2009) and case study examples gained through a community-based participatory research approach (CBPR; Arantes Do Amaral et al., 2018; Minkler & Wallerstein, 2011). The methodological approach did not try to fit an objective ideal of an imagined perfect reality into observations (Kliewer et al., 2004; Montoya et al., 2020). Rather, observations were used to understand a pragmatic reality, and then to explain that reality and apply the explanation in a useful way (Bernstein, 2016). The ethnography was taken via the investigators' roles as classroom instructors in several postsecondary educational settings using project-based learning (PBL) in college, apprenticeship, and adult education settings: a situation in which PBL is suited for data collection (Fruchter & Lewis, 2003).

The theory development is based on an ontology. In ontological theory development, the project follows a formalization of the framework, an application of that framework in a beneficial process, and finally an example of a practical implication of that process. Study 1 of this dissertation is focused on the formalization of the metric and framework. The latter two studies focus on the application of the framework and a practical implication.

Research-Practice Partnership

This study is part of a larger project (Montoya et al., 2018, 2020; Tarantino et al., 2016) which relies on the same Northern California Silicon Valley-based Research-Practice Partnership (RPP). Our RPP included educators and other community participants (i.e., union leadership, policymakers, business partners). Figure 1 depicts the numerous organizations which make up our RPP and together are known as the Santa Clara County Construction Careers Association (S4CA). Our larger partnership includes four high schools, three community colleges (i.e., 2-year colleges), eight apprenticeship programs, an adult education program, and two universities (i.e., graduate and bachelor's degree–granting institutions). This paper focuses on postsecondary education institutions.

Using an ethnographic action research method (Hartmann et al., 2009), roles as instructors and researchers were leveraged to gather various data sources (Table 1). The courses observed employed a project-based learning format to teach virtual design and construction as an implementation of the PBL lab's Architecture Engineering and Construction (AEC) Global Teamwork course (Fruchter & Courtier, 2011; Fruchter & Lewis, 2003). As a team of instructors and investigators, data were collected using field notes, student artifacts, and narrative, and ethnographic notes. Data were collected in the following settings: the postsecondary classroom, informal interviews with interlocutors, and formal meetings.

Postsecondary classroom observations were recorded through daily field notes and ethnographic narratives of postsecondary courses. Field notes were taken directly after courses were taught. An ethnographic narrative style (Shange, 2019) was utilized, which often weaved in personal experience and observations of other courses in the pathway. Informal interviews with

students, colleague researchers, and practitioners who are all part of the broader RPP and ethnography were also utilized. Informal meetings were utilized to discuss curriculum and do member checks for interpretation of data analyses.

Measures

Inductive coding of various data was used to identify key themes of social mobility and perceptions of social mobility.

Sources of Data

Study 1 of this dissertation focuses on my role as an instructor in a postsecondary course, and I leverage data collected from other instructors. Furthermore, these analyses are also informed by dual-enrollment course observations, informal interviews with interlocutors, and various meetings with the greater RPP to collect and analyze data for this study. See Table 1 for an overview of the data collected in this study.

Table 1

Sources of Data

Data Source	Overall
Observation/field notes	182 days of practitioner field notes
Postsecondary classroom observations	100 hours
Dual-enrollment course hours	50 hours
Informal interviews	20 interviews
Researcher meetings	40
S4CA meeting notes	4
Apprenticeship coordinators meeting notes	4

Using an ethnographic action research method (Hartmann et al., 2009), the authors leveraged their roles as instructors and researchers to gather various sources of data. The course takes a project-based learning format to teach virtual design and construction as an implementation of the PBL lab's Architecture Engineering and Construction (AEC) Global Teamwork course (Fruchter & Courtier, 2011; Fruchter & Lewis, 2003). The investigators collected data using fieldnotes, student artifacts, and narrative ethnographic notes. Data were collected in the following settings: the postsecondary classroom, informal interviews, and formal meetings.

Postsecondary classroom observations were recorded through daily fieldnotes and ethnographic narratives by the two instructors in two postsecondary courses. Fieldnotes were taken directly after courses were taught. The field notes employed an ethnographic narrative style (Shange, 2019) often weaving in personal experience and observations of other courses. All of the quotes for Study 1 are from my fieldnotes.

Informal interviews were conducted with dozens of students, colleague researchers, and practitioners who are all part of the broader RPP (Figure 1) and ethnography. Informal meetings were used to discuss the curriculum and do member checks and logic checks for the interpretation of data analyses.

Data Analysis

Through ethnographic participatory roles (i.e., as instructors), inductive codes were analyzed to identify key themes of social mobility and perceptions of social mobility. Researchers/ instructors from both post-secondary courses met weekly to discuss emerging themes in codes.

(RQ1) What current metrics in literature explain functioning AS-CTE education pathways? This question was answered through a literature review, and metrics were tested during the ethnography.

(RQ2) What additional observable metric helps to explain functioning AS-CTE education pathways? This question was addressed through an ethnographic participatory (Hartmann et al., 2009) role (i.e., as an instructor). Data was collected and analyzed through inductive coding to identify key themes of social mobility and perceptions of social mobility. Social mobility is defined as students' perceptions that their workforce pathway can give them a career with a living wage and act as a pathway to a career or to higher education. I met with my team of researchers weekly throughout the course to discuss emerging themes.

Ethnographic Access

To gain access to ethnographic situations and subsequent expert reviews, I relied on community-based participants. These participants come from an existing long-term and close collaboration with the Santa Clara County Construction Careers Association (S4CA). S4CA includes educators from community colleges and trade education centers as well as leaders from the academy, labor, industry, and public policy.

Data was collected in the following settings: the postsecondary classroom, informal interviews, and formal meetings. The postsecondary classrooms were recorded through daily field notes and ethnographic narratives. Several informal interviews with dozens of students, colleague researchers, and practitioners who are all part of the broader RPP and ethnography were conducted. These informal meetings were also used to discuss curriculum and do member checks and logic checks for interpretation of data analyses.

Results

RQ 1: What current metrics in literature explain functioning AS-CTE education pathways?

Applied STEM Career and Technical Education (AS-CTE) research often frames predictors of vocational education success through features like motivation (Lee & Stankov, 2018) and measures success in administrative qualities like leadership (Bartlett et al., 2018). Arantes Do Amaral et al. (2018) found that seven PBL essentials form good learning outcomes. Creghan and Adair-Creghan (2015) found that PBL resulted in higher attendance: a predictor of program completion as shown by Plasman et al. (2021). To contribute to PBL theory, this research pulls from underpinning concepts in AS-CTE as guides in the formalization of a framework that demonstrates an improvement in predictive performance for academic success—keeping the contribution by Plasman and Gottfried in mind—over that last contributed by Creghan and Adair-Creghan.

RQ 2: What additional observable metric helps to explain functioning AS-CTE education pathways?

Building on Plasman et al. (2021) success metrics of attendance as a measure of program efficacy as a point of departure, I claim that social mobility is a necessary metric of measuring CTE pathway success. The results of ethnographies reveal differing degrees of social mobility in traditional postsecondary AS-CTE pathways (community college) and union-led apprenticeship pathways (pipefitters). This study centers on the stories of traditionally marginalized students who would have been considered successful using the seven PBL essentials to predict pathway success (Arantes Do Amaral et al., 2016) and success metrics using attendance as a measure of program efficacy (Creghan & Adair-Creghan, 2015; Plasman et al., 2021). However, their personal stories and struggles are revealing a different narrative. Through the ethnographic role as

a postsecondary PBL AS-CTE instructor, I observed a lack of both social mobility and perceived social mobility by students who would be considered successful by the attendance metric. Given this discrepancy, it is necessary to add social mobility to postsecondary PBL AS-CTE program evaluations as a critical metric of success and program efficacy.

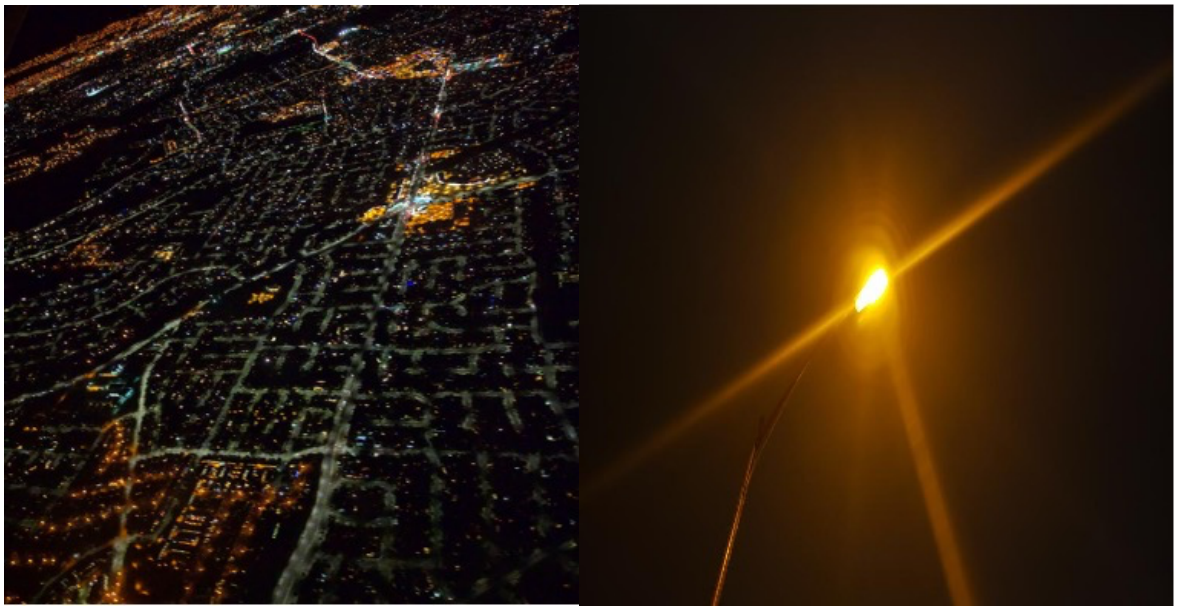
ETHNOGRAPHY-INFORMED ADDITION OF A NEW METRIC

To address the forks and blocks in workforce pathways, the investigators explored the social mobility of these pathways through roles they took as associate faculty instructors at two local community colleges (Willis, 1977). The investigators define social mobility as students' perceptions that their workforce pathway can give them a career with a living wage and act as a pathway to a career or to higher education (Montoya et al., 2018). The AS-CTE course was an implementation of virtual design and construction curriculum with a social and environmental justice focus (Barg et al., 2020; Bick et al., 2021; Brosque et al., 2021; Fischer, 2006; Garcia-Lopez & Fischer, 2014; Montoya et al., 2018; Peng et al., 2021; Peterson et al., 2011; Song & Fischer, 2020; Tarantino et al., 2016; Tayag et al., 2021) taught through Project-based Learning (PBL), following the PBL Lab AEC course format (Fruchter & Courtier, 2011). The investigators experienced the AS-CTE programs from the inside. The fact that the investigators themselves had, years before, been students in these very same programs added a layer of depth. Further, the investigators worked as instructors and mentors in the secondary schools which act as feeders to these AS-CTE programs. This personal familiarity provides a layer of depth and perspective that allows investigators to connect with interlocutors in a unique way that allows for comfortable and authentic sharing. Thus, this study may not be replicable nor generalizable to other sites and populations. The investigators themselves are products of the investigated community. This experience allowed the investigators to interact with students at several stages

of their school and career trajectories. To begin to explore the issues of social mobility, the following narrative will explore a case example of one student who is representative of many.

Figure 7

Aerial photo of the San José setting with sodium and LED lights.



Note. The setting of the ethnography often carried through the before- and after-class discussions under sodium lights pictured on the right. The aerial view on the left shows the city's slow change to LEDs with pockets of sodium lights still in use. These lights will soon be phased out, reminding us of the fleeting temporality of this ethnography. Photos courtesy of Jason Brown. May he rest in peace.

The following is a first-person narrative account of the investigator's first encounter with a student at the postsecondary institution:

"The subtle orange glow of sodium lights greeted me as I walked onto campus for my first postsecondary faculty position. I arrived nearly an hour early, which, according to my grandfather, would be right on time. The only time he stood on a college campus was to work as a laborer. All of his technical skills were learned on the job.

Standing under those antiquated lights, I considered the differences between how my grandfather learned his trade and how my students are learning theirs. A dark figure approached, with every step revealing more of their face illuminated orange. In the youth's eyes, I saw myself, my grandfather, and my community. As we stood face-to-face, I recognized the figure as a former student from my secondary classroom years earlier. Having myself both worked as a laborer and studied at this institution, looking at the student was like looking into a mirror and a time capsule simultaneously. They smiled awkwardly and hesitated, wondering if I recognized them. I did then and have always been able to truly see my students."

This student was well into their twenties and would be categorized as high-performing, with near-flawless attendance in their secondary and postsecondary classrooms. Furthermore, they were a product of that secondary school's feeder CTE program, which in theory should be a functioning pathway for social mobility to both college and career.

Below, the instructor listened to the same student sharing their motivation and background to attend their postsecondary CTE class:

"We got to talking, and although they did well in high school (secondary) and had completed a CTE education program, they could not find a job. In their opinion, the college's residential construction framing course would give them an opportunity to secure a 'good job.' I asked if they ever considered an apprenticeship. They said no. The student preferred community college because they could work during the day."

Although this student had checked all the boxes to transition to a postsecondary education and career pathway, they were still in community college well into their twenties. They were also working an unrelated low-wage job to supplement their career education. This is a result of many factors, including a lack of articulation and lack of dual-enrollment, that hinder social mobility into the high-skill, high-wage workforce.

Arriving early allowed the instructor to speak with many students and hear their individual and collective stories, which were very similar to this student. **The instructor discusses waiting outside the classroom:**

"As an expendable associate faculty instructor, I was not given a key to the classroom. Waiting for the senior instructor to open the door 15 minutes late, I was able to meet nearly all of the forty men and women who were hoping to take my class. Many of these students had similar stories, and already put in a 10+ hour day of work in low-wage non-technical jobs like retail and foodservice."

This student's situation was not unique, and the more the investigators interacted with students in these pathways, the more stories they heard that were similar to this case study student. Furthermore, the investigators are seeing one of our first clear barriers to these students' social mobility. With 40 people showing up to an 18-student-capacity classroom, over half of these eager students will be turned away.

The instructor discusses the issue with limited enrollment capacity:

"With enthusiasm, students asked if they would be able to add the class. The senior instructor replied that they were not sure how many could add and to show up next week. They then released the group and proceeded to explain to me that we needed to cap the class at 18 students."

Impacted CTE programs are common in public institutions. Through this interaction, another potential block to the students' actualization of their social mobility is clear: the lead instructor was not transparent with the students. Many would show up for the next class only to be turned away. These students' time was seen as less valuable than the instructor's time.

The new associate faculty instructor and ethnographer describes their concern for these students' opportunity costs below:

"There were some legitimate safety and logistical concerns for capping at 18, but I was mostly confused that they would not share this with the students. Because the senior instructor was the key master, I kept my questions to a minimum. However, I did comment that we should at least email the students, many of whom commute, rush from work, have babysitters, etc... At the end of the day, these are people with real opportunity costs. I thought it was important to let them know there would be no additions and not to waste their time. The senior instructor's response: just tell them next week."

This dismissive attitude toward students' time permeated much of the postsecondary CTE program. Often, instructors were not invested in the program and scheduled classes in service to senior faculty members instead of considering students' needs first. Furthermore, they were not transparent about program expectations and policies. This was a recipe for inequitable programs where students found themselves in limbo, often remaining consistently a few classes away from certificates and the completion of programs that would theoretically get them into the high-skill, high-wage job market. These experiences reveal that the pathway to work and career has many forks and blocks, and often the results are not fair. Every step forward in research that explains the workforce education pathway is a step towards creating equitable workforce pathways and social mobility for our most marginalized populations.

Intervention Ethnography: A New Awakening Through a Case Study

"Again, I walk to the classroom in the yellow glow of those San José parking lot lights, only now it is the Pipe Trades Education Center that I am approaching. I imagine the same student in the same scenario, with the same excellent attendance, only now, I no longer have the same apprehension for my student's social mobility."

As an apprenticed pipe trades journeyperson, this student will soon make over 130 percent of the regional mean income. In addition to this income, they will have pension-protected benefits, hiring hall, union-negotiated labor standards and job protections, and an

opportunity for continued skills development. This program stands out from the previous ones beyond the measurement afforded by metrics of AS-CTE and attendance.

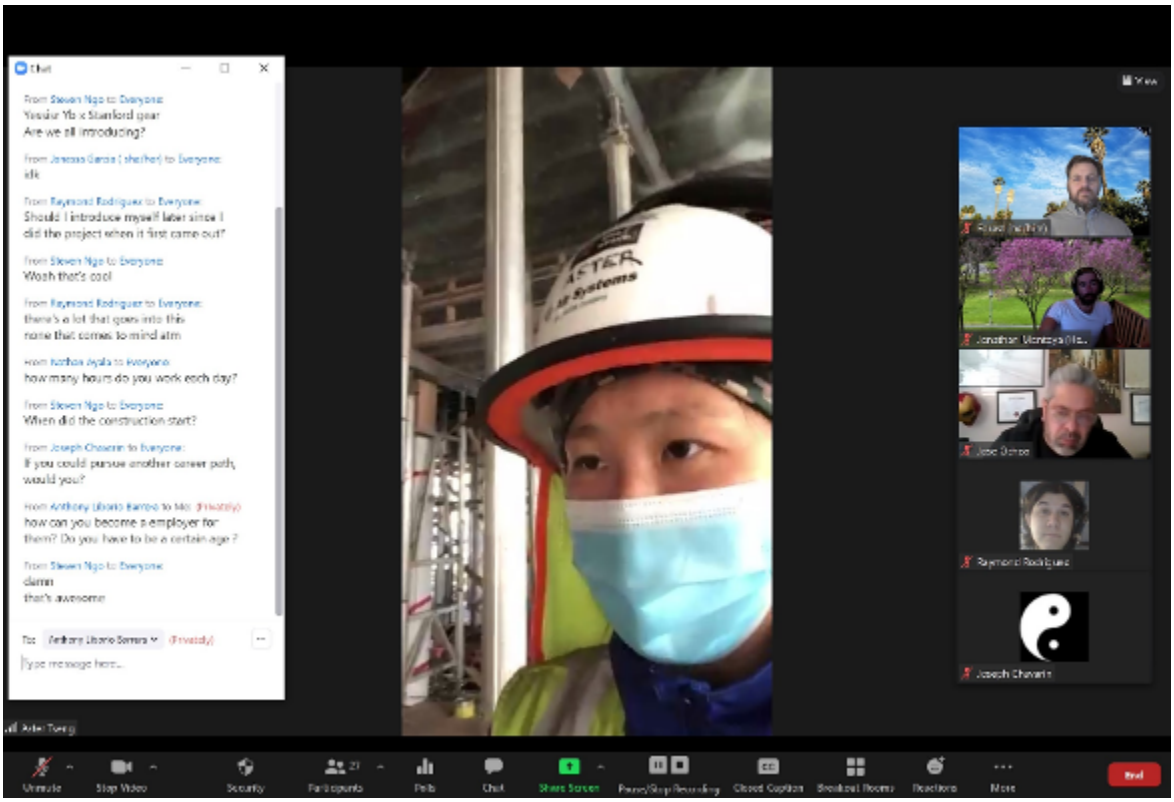
At the Pipe Trades Education Center, my role is that of a guest to observe an often-unseen reality in CTE education. The Center is administered by a trade union, and without a specific reason to be on that site you would not know it exists. A complex of clean, low-rise education buildings is tucked away adjacent to a commercial zone, with a solidly constructed iron fence protecting the site.

The investigators participated in the apprenticeship education system as guests – one describes the social mobility the students enjoy:

"It started as a simple call and a request to grab a coffee and talk about apprenticeship education. From collaboration with and numerous visits to the Pipe Trades Education Center, I was familiar with this apprentice. They had already given guest lectures in courses I taught as an associate faculty. "Just meet me at my worksite, there is a coffee shop across the street!" The contrast between the student in their 'street clothes' and the student in their 'work clothes' was one that as a concrete laborer I understood—that feeling that says, "See, I am a person."As we sat in an upscale coffee shop in the heart of the Silicon Valley venture capital financial district, surrounded by startup teams, we were as socially mobile as everyone around us. We could have pitched a startup just as easily as talked through the human rights this student learned about in their labor course. That this student was employed full-time in a high-skill high-wage occupation seemed secondary, given all the other opportunities we discussed."

Figure 8

The classroom



Note. An investigator visiting the 'classroom' of an apprentice pipe trades student: the student leads their PBL AS-CTE class through a job site walkthrough. Screenshot Montoya

Discussion

CONTRIBUTION TO THE FIELD

Building on Plasman and Gottfried's (2020) success metrics of attendance as a measure of program efficacy as a point of departure, the authors claim that social mobility is a necessary metric of measuring CTE pathway success. The results of ethnographies reveal differing degrees of social mobility in traditional postsecondary AS-CTE pathways (community college) and union-led apprenticeship pathways (pipefitters). This study centered the stories of traditionally marginalized students who would have been considered successful using the seven PBL essentials to predict pathway success (Arantes Do Amaral et al., 2016) and success metrics using attendance as a measure of program efficacy (Creghan & Adair-Creghan, 2015; Plasman &

Gottfried, 2020). However, their personal stories and struggles described in this ethnography reveal a different narrative. Through their roles as postsecondary PBL AS-CTE instructors, the investigators observed a lack of both social mobility and perceived social mobility for students who would be considered successful. Given this discrepancy, social mobility should be added to the postsecondary PBL AS-CTE ontology as a metric of success (used for example in program evaluations).

IMPLICATIONS

This ethnography left a bleak vision of how the workforce has been sold versus the reality of historically marginalized students. However, there is a glimmer of hope in the counter-narrative of the pipe trades. The authors identified that social mobility is a metric of success for the pipe trades, and suggest that trade programs strive for this metric which improves on attendance alone as a predictor of success. While the authors observed many other interesting metrics, as researchers the authors identified a concise contribution in social mobility which itself encompasses many program-specific metrics which may detract from the greater PBL AS-CTE contribution. To move toward an equitable future for those in the workforce and education system we need work to problematize the historical roots of workforce pathways. While looking to the future of Silicon Valley PBL AS-CTE education, we must be cautious to avoid superficial amelioration of past harms caused by these pathways. Let us first take the palimpsest of the workforce education recipe and scrape away the prescribed instructions, analyzing each layer to avoid rewriting historical injustices. This recipe must be critically examined in order to be more justly rewritten. By observing the pipetrades' potential for social mobility, we propose the implementation of an improved predictive measure: that social mobility be added as a metric to a predictive ontology framework of education success. Through the counter-narrative, this study envisages a socially mobile workforce—one where classes are articulated to postsecondary institutions, students earn a living wage, and their health and safety are protected. This is not a pipe dream: it already exists in our region in trade education such as the Pipe Trades Education Center.

This study forces us to acknowledge past harms caused by CTE programs in marginalized communities such as San José. Al Garza and Herman Gallegos have shared details of these toxic pathways and their impacts on marginalized communities in Silicon Valley (Martinez, 2017). Project-based learning curricula such as workforce VDC have shown promise in helping to mitigate such harms. However, the implementation of Workforce VDC may simply postpone the inevitable reality that these programs must either be radically reimagined or dissolved entirely.

SIGNIFICANCE OF IMPACT

This study lends insight into the ways that postsecondary Career Technical Education institutions struggle to fulfill their mission to increase employment and social mobility for students from marginalized communities. Historically, access to education is not enough. Groeger (2017b) reminds us that, "increased access to education, so often hailed as a road to opportunity, gave rise to a new form of social inequality in the modern United States." Groger's critique highlights 'credentialism,' where unequal access to education credentials perpetuates an elite ruling class (Groeger, 2021). This inequality is mirrored in neighborhoods in Silicon Valley. Recent research from Montoya et al. (2018) found poor environmental factors as students completed a safety survey of the routes to their school. The students were then transported to an affluent community where they did another survey and for the first time had a comparative lens to see inequities in both their schools and their environments. This study examines whether inequities reach further than the built environment and extend to their postsecondary CTE facilities.

Not all communities are created equal, and knowing to what degree each postsecondary institution generates social mobility allows for recommendations towards best practice. The investigators are motivated by service to their community and aim to inform community stakeholders which institutions are functioning to facilitate their workforce mobility. Too often, underrepresented minorities and/or low-income individuals carry the burden of social and environmental injustices that impacts their livelihood and lack of mobility. In the high-tech region, neighbors are exposed to environmental stresses and contaminants that measurably impact community health (Montoya et al., 2018). Furthermore, many live with neurotoxins like

lead paint, carcinogens like asbestos, or in close proximity to brownfields and manufacturing facilities of unknown and mixed pollutants (Montoya et al., 2018).

As one of the wealthiest regions in the country, the Silicon Valley has impacted communities—composed mainly of minority individuals—that are nine times more likely to reside near toxic facilities and sites (Massey, 2004). Efficient postsecondary PBL AS-CTE pathways help to ameliorate these environmental and structural inequities by providing true pathways to job skills that will result in higher wages.

Uncovering and creating these functioning pathways through PBL AS-CTE helps to increase a homegrown skilled workforce. Job skills and prosperity allow community members to improve the environmental impacts of buildings around them and to join a growing and prosperous workforce (Fischer, 2006; Peterson et al., 2011). These studies have the potential to help bridge these gaps to postsecondary AS-CTE for a community with a historically underrepresented population that has struggled to enter the college–career pipeline and construction management field.

Conclusion

In conclusion, I recommend that researchers, administrators, and policy makers add social mobility as a metric to a predictive ontology framework of education success.

LIMITATIONS AND SUGGESTED RESEARCH

Union apprenticeship programs, like the Pipe Trades Education Center featured, are currently the most apparent pathway to the university. Important concepts, such as social justice, are derived through academic equivalency which creates social mobility. The apprentice described in this paper would never be allowed to teach even a CTE community college course whereas the investigators, due to their advanced degrees, would be able to even if they knew nothing specifically of the topic they were teaching.

Researchers should further explore pathways from the apprenticeship to regional university undergraduate programs, bargained agreements of recognized academic equivalency

by industry companies, potentially across industry sectors if that option becomes available in the United States. As best as I can tell, the pipe trades program had a lower overall cost per student; however, budgets which undoubtedly are public information were not interrogated for this study. Following the example of The European Credit Transfer and Accumulation System (ECTS), the investigators recommend exploring academic credit for knowledge gained through experience, including experience in elected executive-type roles within labor organizations. Last, workforce education centers should be administered by those who have participated in the relevant workforce. Looking ahead, a legislated direction may be necessary to move these recommendations forward to implement social mobility as a metric of predicting PBL AS-CTE program success.

The investigators are aware that, given the nature of their positionality and particular lens, these ethnographies cannot and should not be generalized beyond our unique setting. These analyses are specific to the investigators, and although the investigators have made every effort to avoid blind spots and misinterpretations to accurately describe these students, their experiences, and their pathways, these analyses could not be replicated because they are unique individuals during a unique time.

This study did not explore the pathway of academic equivalency as thoroughly as intended. As ethnographers, much of the pace of research is dependent on real developments by a community of participants that the ethnographers do not and should not have an influence on. This study was conducted during a pandemic and accompanying economic collapse and political upheaval. That said, the investigators present a PBL path forward for AS-CTE students through academic equivalency and reentry to the academy of higher education.

Study Two – Student Perceptions of AS-CTE

Research Question

1. If given an opportunity to learn virtual design and construction through project-based learning, to what degree do underrepresented and/or low-income youth perceive the building industry as a career?

Methods

Participants

The CBPR participants come from organizations with an interest in Career Technical Education. These organizations come together as the Santa Clara County Construction Careers Association (S4CA) every three months. These meetings include administrators and instructors from community colleges, public high schools, joint apprentice training centers (pipefitting, electrical, sheet metal, and carpentry), universities, and adult education programs, as well as labor leaders from the building trades council, business leaders from construction companies, and political leaders from the regional government. This community forms the core of this research and provides a base of participants.

Content and demographic data include three secondary education institutions in an underrepresented, predominantly Latinx and low-income community in East San José, California. West Mendez high school and Big Piper high school are the pseudonyms for the two public secondary schools surveyed from the same school district, which is given the pseudonym Union High School District. Two private all-girls schools given the collective pseudonym St. Champaign are included as a composite exemplar of schools on the other side of the opportunity gap.

Setting

The Union High School District represents the background population of the underrepresented community. This community has one-tenth of the admission rate to top-tier universities as affluent communities (54% are considered university-ready with A-G course requirements, though many would feel unprepared for a university). The standard CTE shop class size is thirty-five students. Each district school graduates roughly 500 students per year. The district is predominantly Latiné (52%) and lower income (47% of students qualify for free and reduced-price meals; Ed-Data, 2020).

St. Champaign represents a PBL education available to the elite population that does not have an opportunity gap. These schools have a ten-times higher admission rate than affluent communities to top-tier universities (94% attend a four-year university). They have an average class size of ten students. Each school graduates fewer than two hundred students per year. The demographic is predominantly non-Latina (13% Latina) and upper income.

Procedure

I used narrative ethnography to uncover students' perceptions of building industry careers and utilize a 5-point Likert scale survey modified from a validated 7'C's survey (Ferguson, 2012) to measure their perceptions in seven categories. A PBL pilot group of six high school students were chosen as case study students, and their presentations and projects were be analyzed. Their surveys were checked against two control groups from the same high school (West Mendez). Group A, a non-PBL construction technology course. Group B, a general population group that fits the profile of the regional community. Control Group B's main difference from control Group A has an equal distribution of male and female students as well as

the inclusion of university-track students. As a final comparison, two all-girls private institutions (St. Champaign) that are not subject to the opportunity gap were surveyed.

The survey allows benchmarking of the Union High School district PBL experiment group (disrupted opportunity gap) with their general population (undisrupted opportunity gap) and then compared to the private school population (non-opportunity gap) see table 2 for groups. To evaluate the survey results for a measured shift in perceptions, the experiment group was compared to control Groups A and B. Comparing perceptions to non-opportunity gap schools helps to see what discrepancies, if any, can be ameliorated from the role of the opportunity gap.

Table 2

Students by group

Group (Pseudonym)	Number of students
Group A non-PBL construction technology course (West Mendez CTE)	114
Group B (West Mendez General pop)	166
Composite all-Girls School (St. Champaign)	26
PBL experiment Group	6

Measures

As this is part of a larger study, the student perception survey measured perceptions in 7 categories: Building Energy Efficiency, Sustainability, Positive Environmental Education, Teacher Support, Confidence, Social Justice/ Community, and Knowledge of Career Options/ Possible Careers for them. This study focuses primarily on the last category, knowledge of careers and the perceived possibility of actualizing those careers. The ethnography employs

inductive coding of all data sources looking for instances of knowledge of career options and student perceptions of their ability to actualize these careers.

Table 3

Sources of Data

Data Source	Overall
Observation/field notes	182 days of practitioner field notes
Researcher meetings	40
Presentation slide decks	4
Case Study Student Surveys	6
Group A Student Surveys	114
Group B Student Surveys	166
St. Champaign Student Surveys	26

Analysis Plan

(RQ) If given an opportunity to learn virtual design and construction through project-based learning, to what degree do underrepresented and/or low-income youth perceive the building industry as a career?

Ethnographic methods were the primary means to address this question and to uncover students' perceptions of building industry careers. These perceptions were discovered through in-depth ethnography and checked with a student perception survey. Narrative ethnography was employed through field notes and lived experience as a former high school construction technology instructor. Conversations with interlocutors and informal interviews with research

partners were leveraged to check observations and insights of my ethnography. I met with a research team weekly to discuss emerging themes and codes. For ethnography and survey analyses, students are divided into four groups to help with sorting data and guide the coding of ethnographic data. Individual identifiers were omitted to ensure student anonymity.

The following four groups were compared: The experiment group includes an all-male group of students in a PBL-VDC course (n = 6). Two control groups from the same high school (West Mendez) as the VDC group completed the perception surveys. Group A is a non-PBL student group in the other construction technology courses (n = 114). This group closely parallels the experiment group's demographics: made up of predominantly male, Latinx, and non-university-track students. Group B is a general population group (n = 166). This group fits the profile of the regional community. Control Group B's main difference from control Group A is an equal distribution of male and female students and the inclusion of university-track students (64% meet state university entrance requirements). Finally, I surveyed two all-girls private institutions and gave them the pseudonym St. Champaign. These schools are not subject to the opportunity gap (n = 26).

The four groups of students mentioned above completed a 5-point Likert scale survey with a range of totally true to totally untrue. The employed survey was modified from a validated 7'C's survey (Ferguson, 2012). I used this survey to measure student perceptions in seven categories (see Appendix) independently from ethnographic observations. Individual student identifiers such as age and gender were not used for survey data collection. Instead, I considered their collective demographics when analyzing survey results to draw insights and guide ethnographic analysis. I employed collective categorical identifiers. For example, the all-girls private schools were combined and categorized as a composite singular all-girls school. This

composite helped to ensure school anonymity as there are very few schools of this type in our area, and I want to honor the request of my interlocutors for anonymity. When analyzing data of all-girls private schools, I met with interlocutors to ensure their perceived anonymity was met. I understand the limitations and complexity of gender identification, so I refer to the school collectively and not the individual students.

The surveys were distributed by the students' instructors and returned to me without any student identifiers, only split into four categories by the four groups mentioned above. The private girl's schools were combined into one stack and analyzed. The surveys were physically scanned using Remark software provided by the partnering public school district. The survey allowed for benchmarking of the Union High School district experiment group (disrupted opportunity gap) with their general population (undisrupted opportunity gap) and then compared to the private school population (non-opportunity gap). Student perceptions were evaluated, for differences in student perceptions by group, and the survey results were compared by the percentage of student responses in each category.

Thus, with ethnographic observations and a 5-point Likert scale survey, this study explores how youth from low-income and underrepresented backgrounds perceive the building industry as a career when given an opportunity to learn VDC through PBL. These surveys were used to explore the perceptions of students identified as not experiencing an opportunity gap and how they perceive the building industry career opportunities.

This research relied on a community-based participatory research (CBPR) platform. Primarily, it is an ethnography (Hartmann et al., 2009; Montoya et al., 2021). Roles as instructors and researchers were leveraged to collect data using fieldnotes and narrative ethnographic notes.

A *5-point Likert scale* survey then provides a measure of students' perception shift. Due to this mixed approach, support from a community of organizations is crucial for ethnographic access and survey implementation. The private all girls' schools maintain an excellent reputation in the community and do not stand to gain anything from their participation in this study. However, the addition of a survey offers a clearer understanding of ethnographic observations. All secondary school names in the study are pseudonyms inspired by landmark cases in education.

The CBPR participants are members of organizations with an interest in Career Technical Education. These organizations come together as the Santa Clara County Construction Careers Association (S4CA) every three months. These meetings include administrators and instructors from community colleges, public high schools, joint apprentice training centers (pipefitting, electrical, sheet metal, and carpentry), universities, and adult education programs, as well as labor leaders from the building trades council, business leaders from construction companies, and political leaders from the regional government. This community forms the core of this research and provides a base of participants.

Our content and demographic data include three secondary education institutions in an underrepresented, predominantly Latiné, and low-income community in East San José, California. West Mendez high school is the pseudonym for the public secondary school surveyed, and Big Piper high school is the pseudonym for the other secondary school in the same school district, called Union High School District. Two private all-girls schools, given the pseudonym St. Champaign, are included as a composite exemplar of schools on the other side of the opportunity gap.

- The Union High School District represents the background population of the underrepresented community. This community has one-tenth of the admission rate to top-

tier universities as affluent communities (54% are considered university-ready, though many of those would feel unprepared for a university). The standard shop class size is thirty-five students. Each district school graduates 500 students per year. The district is predominantly Latiné (52%) and lower-income (47% of students qualify for free and reduced-price meals) (Ed-Data, 2020).

- St. Champaign represents a PBL education available to the elite population that does not have an opportunity gap. These schools have a ten-times higher admission rate than affluent communities to top-tier universities (94% attend a four-year university). They have an average class size of ten students. Each school graduates fewer than two hundred students per year. The demographic is predominantly non-Latina (13% Latina) and upper income.

Following Willis' (1977) seminal ethnography Learning to Labour, the authors employed ethnographic methods to uncover students' perceptions of building industry careers. These perceptions can only be discovered through in-depth ethnography and corroborated with perception survey data. The lead author took on an ethnographic role as a high school construction technology instructor. The author completed a one-year introduction to the VDC course with several colleagues. The author next formed a PBL pilot with a voluntary group of eight high school students to learn VDC principles and methods. Six of the eight students finished the year-long program. In the spirit of a building retrofitted with measurable metrics (Jafari et al., 2014), a sidewalk served as an example of a construction to be analyzed and repaired for efficiency. This example provided both a physical component with measurable properties of quality and a metaphorical social justice component from the viewpoint of public

policy for civil infrastructure. To center sidewalks as a focus, students were challenged to complete a safety survey of routes to their school (Kim et al., 2016). The students were then transported to an affluent community, where they did another survey. Over six months, the students applied VDC methods to their data, and at the end of the academic year, they made a final presentation of their results to industry mentors.

The ethnography provides depth of insight, and to gain a higher level of understanding across populations, surveys were also implemented to gauge student sentiments. Four groups of students completed a *5-point Likert scale* survey modified from a validated 7Cs survey (Ferguson, 2012) to measure their perceptions in seven categories (Appendix) independently from the ethnographer's observations. The experiment group included the students in the PBL-VDC course (n = 6), an all-male group. There were two control groups from the same high school (West Mendez) as the VDC group. Group A was non-PBL students in other construction technology courses (n = 114). This group closely parallels the experiment group's demographics: it was made up of predominantly male, Latinx, and non-university-track students. Group B was a general population group (n = 166). This group fits the profile of the regional community. Control Group B's main difference from control Group A is an equal distribution of male and female students as well as the inclusion of university-track students (64% meet state university entrance requirements). Finally, two all-girls private institutions were surveyed and given the composite pseudonym St. Champaign. These schools are not subject to the opportunity gap. (n = 26).

The survey allows benchmarking of the Union High School District experiment group (disrupted opportunity gap) with their general population (undisrupted opportunity gap) and then compared to the private school population (non-opportunity gap). To evaluate the survey results

for a measured shift in perception, the experiment group was compared to control Groups A and B. Comparing perceptions to non-opportunity gap schools allows us to see what discrepancies, if any, can be ameliorated from the role of the opportunity gap. The authors use this information to theorize on why social mobility is restricted for students of lower socioeconomic status.

Thus, with ethnographic observations and a *5-point Likert scale* survey the researchers have explored how low-income and or underrepresented youth when given an opportunity to learn VDC through PBL perceive the building industry as a career. These surveys were also used to explore the perceptions of students who were identified as not having an opportunity gap; and how they perceive building industry career opportunities.

Results

RQ: **If given an opportunity to learn virtual design and construction through project-based learning, to what degree do underrepresented and/or low-income youth perceive the building industry as a career?**

Ethnographic results show PBL increasing student engagement while participating in teams. Observations showed students become leaders in their schools and agents of change in their community. VDC related to real environmental and social issues also empowered students in their projects.

The purpose of this research was to discover the degree to which low-income and or underrepresented youth perceive the building industry as a career if given an opportunity to learn VDC through PBL. There are two institution categories in the survey sample: West Mendez high school within the public Union High School District and St. Champaign, a composite private all-girls school.

Ethnography Observation

Note to reader: This ethnography section is written in a narrative ethnographic style.

An ethnography allowed me to see students participate in a scientific process through three components of project-based learning. First, I identified teamwork as a crucial component of a PBL-VDC curriculum. Second, the students showed me their command of authentic PBL. Last, I observed real student engagement in the course.

PBL is effective at increasing student engagement in teams. I leveraged that PBL pedagogy effectiveness to increase student engagement in the course. With this engagement in mind, I introduced themes of VDC. During this pilot course, students improved their ability to work together. I saw my students become leaders in their school and agents of change in their community. VDC related to real environmental and social issues that they could see, which helped me harness my students' frustration and curiosity. I watched as they identified problems in their community and became empowered to change their own lives.

Change was on my students' minds when they started the safety survey of routes to school. They picked a typical route to school in their neighborhood and surveyed that route. Then, they surveyed a similar route in an affluent neighborhood and compared their experiences. The students took on the roles of social scientists and civil engineers as they analyzed sidewalks in these very different communities. They grappled with qualitative and quantitative data as they experienced their surroundings with all their senses. This analysis became more than a simple survey. The sidewalks reflected the invisible walls and barriers to the students' own social mobility. When surveying the affluent neighborhood, they commented feeling like foreigners. They were actually initially afraid and ashamed to walk around the second neighborhood; however, residents were welcoming and intrigued by their study. These feelings signal a point at

which many students would close themselves off and internalize their perceived inequity. This realization of inequity, without a way to channel their efforts to change it, could perpetuate traumas that students have already internalized. Too often, moments like these are where youth begin to become the negative internal thoughts of what they believe society really wants them to be.

At this crucial point, I saw why VDC was important to our youth. Rather than ruminating on these feelings and stagnating, they were empowered to use VDC terminology to describe their anger at the injustices they observed. The sidewalks were no longer just unfair; they were now 'underperforming design criteria.' They were no longer just ugly-looking; they had measurable metrics of concrete cracks and slab upheaval. These sidewalk defects were not inherent to their neighborhoods but resulted from bad construction and inferior materials. All of this could be remediated with proper construction and an efficient timeline.

After determining exactly how the sidewalks were defective, the students were then empowered to make recommendations and create a construction schedule to fix the problem. They used metrics such as square feet and estimated cost. Further, students considered where materials would come from and whether their proposals were buildable and sustainable. They felt a call to action. They took the initiative to organize a neighborhood clean-up which their mayor attended (Figure 9). As in Freire's (2000) praxis, the students' discovery of their ability to transform material conditions was not purely intellectual or emotional but involved action and serious reflection.

What my students experienced could be written off as an anecdotal feel-good story of disadvantaged youth. But in conjunction with true PBL, the VDC curriculum ensures that their experience does not have to be anecdotal. If widely implemented, this curriculum could be a step

toward social equity and environmental justice. Through my ethnography, I discovered that among underrepresented youth, this PBL-VDC curriculum increased the perception that the building industry could be a career. However, the curriculum seems to have also had a much greater effect on the students' lives.

In parallel to the students' safe routes survey, the Center for Integrated Facility Engineering (CIFE) at Stanford University held a two-day building information model (BIM) Bootcamp for Union high school district students (Figure 10). CIFE's BIM Bootcamp was open to all, with room for more than just the VDC-PBL course students. After the two-day course, the students received a CIFE certificate in BIM to add to their resume or application to an apprenticeship education program.

No two BIMs the students made were the same (Figure 11). Each student created their design while interacting and collaborating with their instructors and classmates. It was amazing to see how students responded to a program and concept (BIM) they had never seen before. Students who tended to disengage in academic settings were excited to learn and express themselves through design. According to the lead instructor, the youth performed on par with typical graduate students.

Figure 9

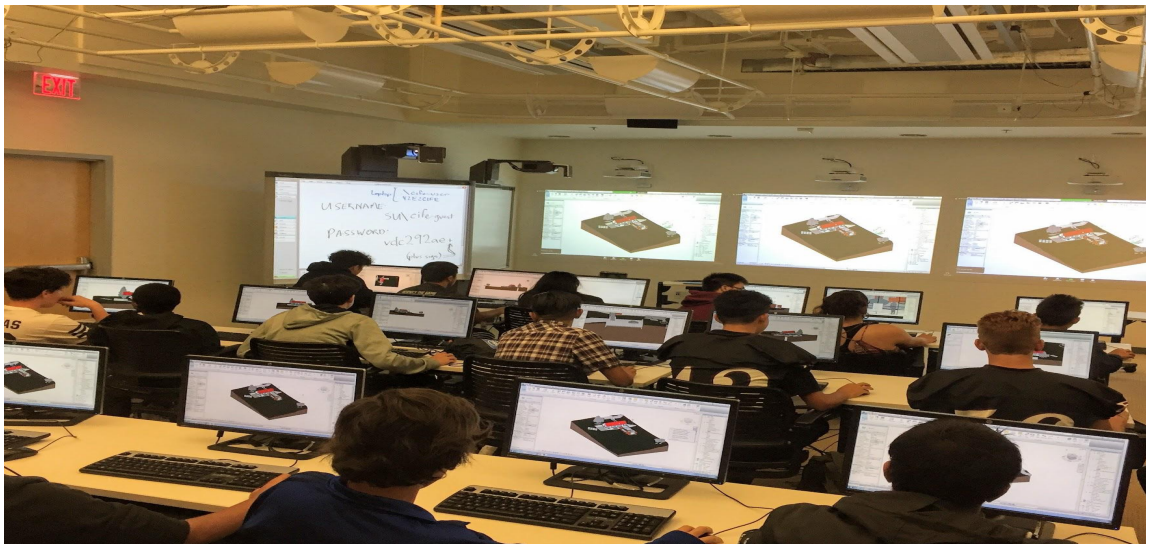
Neighborhood cleanup organized by VDC students and attended by Mayor Sam Liccardo.

Note. Students stop for a photo opportunity with Mayor and Stanford Lecturer Sam Liccardo.

Photo Montoya.

Figure 10

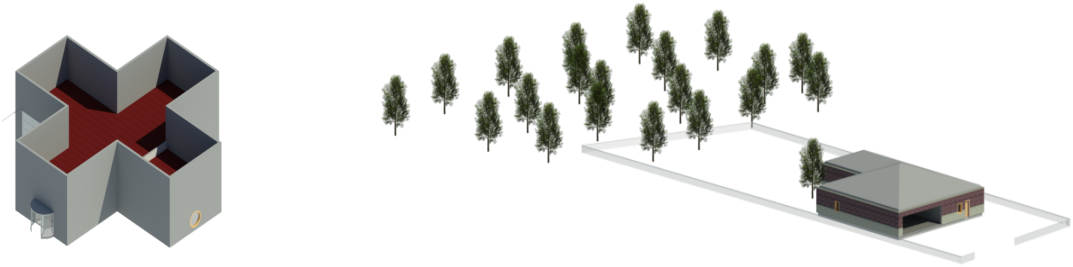
Building Information Modeling Bootcamp at the Center for Integrated Facility Engineering



Note. At a two-day event, students learn to create Building Information Models (Montoya et al., 2020).

Figure 11

Typical student BIMs after the second day of instruction.



Note: Typical student BIMs after the second day of instruction (Montoya et al., 2020).

Survey of Perceptions

The survey data showed the degree to which underrepresented youth shifted their perception of the building industry as a career and pathway to education after a PBL-VDC

course. Through ethnographic observations, it was evident that PBL-VDC helped interest the youth demographic in environmental justice. This section measures whether the observed evidence that PBL-VDC engenders interest in environmental justice also motivates students to consider a building industry career.

Rather than employing pre- and post-surveys, student perception surveys were used with different cohorts. Group A, a demographically similar class with similar instruction to the intervention group, but no VDC curriculum, acted as a control to see if the VDC curriculum was the cause for change. An experimental group was also compared to a general population of non-construction students. Two prestigious all-girls schools (St. Champaign) formed another comparison group as an exemplar of an education that does not experience the opportunity gap.

Both ethnography and survey data illustrated a shift in the student mindset. By the end of the course, students could look past the social stigma surrounding building industry careers. By learning VDC and visiting Stanford University, the students realized the rigor and benefits of building industry careers. The survey shows that participating VDC students were over 25% more likely than St. Champaign to see themselves working in a building industry career. The data reveals that with our PBL course, a group of 14- to 17-year-olds successfully saw a career in VDC and participated in that field. This level of career immersion in VDC is unheard of at a high school level in the United States.

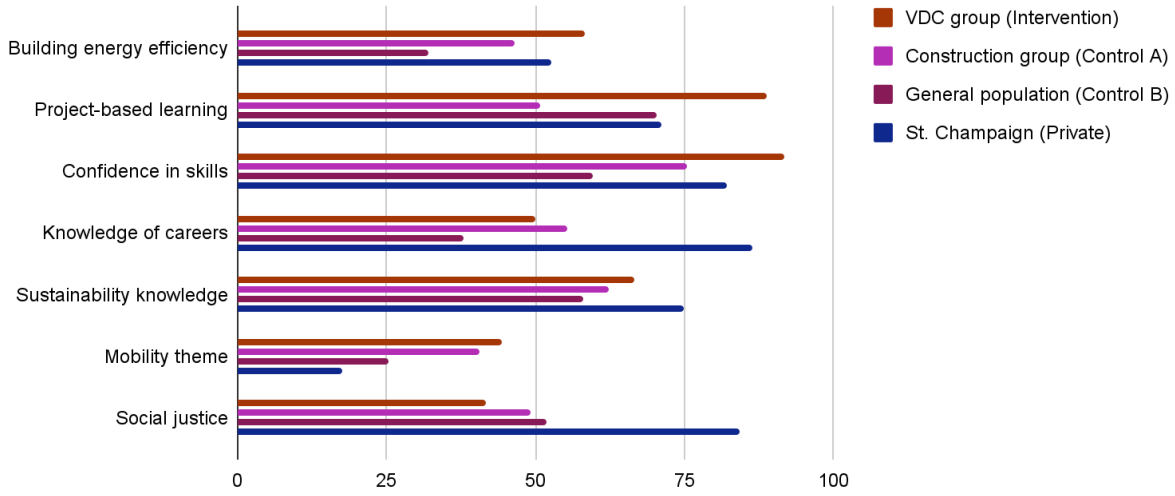
This level of inclusion in their built environment is a form of true social justice because, as observed through the experience of teaching these students, they now feel like participants in change rather than passive bystanders to inefficiency in their environment. Through PBL and VDC collaboration, not only does the built environment open up to public stakeholders, but more

importantly, it humanizes our most marginalized students, giving them space to become agents of social change (Freire, 2000).

The survey measured the degree to which the intervention PBL-VDC curriculum achieved our educational platform goal: **"*If given an opportunity to learn virtual design and construction through project-based learning, to what degree do underrepresented youth perceive the building industry as a career option?*"** The survey contained questions on seven topics: knowledge of career opportunities, social mobility, energy efficiency, project-based learning, confidence in capabilities, sustainability, and social justice (Figure 12). Two of these categories addressed the research question: knowledge of career opportunity and social mobility.

Figure 12

Student Perception Survey



Note. Student perception of construction technology as a pathway. These are the percentage of student responses for the intervention group (construction VDC), control group A (construction technology from the same high school as VDC group), control group B (general student population from the same high school as VDC group), and St Champaign (private).

Goal 1: Narrow the Opportunity Gap

Knowledge of career opportunity: The survey measured students' knowledge of building industry careers. To see themselves pursuing careers in this field, they must first know about it. Half the VDC cohort could see themselves following a career in the building industry. The VDC cohort is 12% more knowledgeable about building industry careers than the general population. Twelve percent equates to four additional students per class. This trails behind the 86% of private school students who are aware of careers in the building industry.

Social mobility: The survey measured student perceptions of social mobility through the trades. Mobility means that students perceive that trades can give them a career with a living wage and act as a pathway to higher education. Of the VDC cohort, 44% saw trades as a pathway to success and prosperity, 20% more than the general population. Given a standard class size of thirty-five students, a 20% shift in perception translates to seven students per class more than the general population. While 86% of St. Champaign's responses showed knowledge of career opportunities, only 17% of students saw the trades as a chance for their personal social mobility, which could be due to already existing at an upper boundary of society. In addition, as noted by Montoya et al. (2020), the female students at St. Champaign experience a gendered opportunity gap. Both of these possibilities invite further investigation.

Goal 2: Teach Virtual Design and Construction

Energy efficiency: 58% of the VDC cohort answered positively to questions about building energy efficiency. VDC students answered 26% higher than the general population. The VDC curriculum has moved nine more students per class toward understanding building energy efficiency. However, at the private all-girls schools, 71% of respondents knew about energy efficiency.

Project-based learning: The students' satisfaction with project-based learning was high for all cohorts. After participating in project-based learning, 89% of the VDC cohort felt increased satisfaction with their learning. This is 20% more than the general population, representing eight additional students per class. This was also 11% more than the private all-girls school.

Confidence in capabilities: The largest impact of PBL-VDC was a change in students' confidence. 91% of the VDC cohort answered positively when asked about their confidence in their abilities. That is 30% higher than the general population and 9% higher than the private all-girls school. The PBL-VDC curriculum increased confidence for ten students per class.

Goal 3: Explore Careers in Sustainability and Topics of Environmental Justice

Sustainability: The students' awareness and understanding of sustainability increased. 66% of the VDC cohort identified that they knew and valued sustainability practices. That is 8% higher than the general population, or three additional students per class. This is behind the 75% at the all-girls school.

Social justice: Although the VDC curriculum has a social justice component, there was no demonstrated increase in the students' awareness of social justice. Of the VDC cohort, 41% scored positively on social justice-themed questions. This is 10% lower than the general population, which is three students per class. When we look at the 84% positive response from the all-girls school, we see that VDC has failed to increase social justice awareness.

The survey data shows that the VDC curriculum increases student confidence, which is important for them to take charge of their future. This class also exposes students to the building industry and makes them more likely to choose building-related careers. However, the all-girls school responses show that though they saw the pathway for success, they did not see it as a

pathway for themselves. We posit that this discrepancy is due to gendered norms in building trades, which warrant further investigation.

The VDC curriculum provides a pathway for future success, not only for the students but also for the industry. While the perception survey provided some concrete quantitative data, the results of the ethnography are more difficult to measure. Observations from the ethnography find a discrepancy in student perceptions of social justice that requires more research.

Discussion

How society perceives its students is as essential as changing students' perceptions. Students will often conform to society's expectations of them. Society needs to hold students to high standards while providing both the rigor and scaffolding to achieve those standards. This contribution from society is crucial to change students' perceptions of their future and their capabilities.

Through the research presented in this paper, the authors have found a benefit in formalizing the implementation of social mobility as a measurable metric through teaching social justice-embedded Virtual Design and Construction methods through project-based learning. This formalization contributes to opportunity gap theory with an improved understanding of the role that education has in shaping perceptions of opportunity, social justice, and social mobility through a disruption and narrowing of the opportunity gap. It also contributes to Workforce Virtual Design and Construction theory with another explanation of how the workforce and VDC interact. Specifically, this study looks at the perceptions of youth, underrepresented in these pathways have about the building industry as a potential career and pathway for higher education to achieve social mobility.

As an ethnographer, I experienced an educator's role in understanding students' perceptions and constructs. The ethnography has an added depth: a decade ago, I was in the same seat as the students, in the same shop class, looking forward to the same prospects with the same background. I share the students' unique constructs. This relation is not so different from the relation of (Willis, 1977) to their subjects in the seminal ethnography, "Learning to Labour." Willis followed a group of British 'lads' as they transitioned from secondary education students to entry-level apprenticeships. In the process, the subjects of the ethnography disclosed their feelings of detachment from their community. This situated observation forms a powerful ethnography. My unique insights into the students' lives and shared demographics are concise and pull from a broad understanding that cannot be drawn solely from an observational study or survey. I am left to ask: did the 'lads' from Willis' study experience an opportunity gap? Almost certainly. If the 'lads' had not experienced an opportunity gap, the story of 'Learning to Labour' would be a different one.

For an example, imagine an implementation of the PBL-VDC curriculum at the lads' school in the UK. This course would be an inversion of workforce tracking: the lads' workforce tracking placed working-class students in working-class courses—non-university pathways. Those students then found themselves forgotten at the toxic margins of a technological society and the associated select high-tech careers. The PBL-VDC curriculum at the lads' school would realize and actualize change in and for their condition as the heart of social justice education. The goals of social equity cannot be replicated in settings outside the realities of working-class conditions. This is the educational framework for social change through PBL-VDC. We place the lads in the framework to follow a stacked pathway of education credentials that lead them to both careers and, if they so choose, higher education. Through PBL-VDC the lads find that the

opportunity gap is closed and they can explore the humanities topics of social and environmental justice that are often reserved for select students. While the traditional banking model (Freire, 2000) of education limits students ability to view themselves as agents of social change, a PBL-VDC model gives them space to develop a critical consciousness; ultimately, they "come to see the world not as a static reality, but as a reality in process, in transformation" (Freire, 2000 p. 83).

My lived experience and ethnographic background bring an understanding of the bigger picture in East San José: this is East Silicon Valley. As Ladson-Billings (2013) reminds us, "There is something deeply un-American about not allowing entire groups of people to participate equitably in an educational system that allegedly provides an opportunity for social and economic advancement." Those living in the Silicon Valley are privy to some of the greatest advancements in modern technology. Starting sixty years ago with IBM's Cottle Road campus in South San José, these neighborhoods have transformed from rural farmlands to urban start-ups and high-rises. Stories of young tech billionaires flood social media and fuel the hopes and dreams of Silicon Valley youth. While other young people might aim to emulate their favorite actors and sports stars, many strive to be tech giants in this valley.

> *As a classroom teacher, I used to hear: "I'm the next Kobe Bryant." (RIP Mamba). That narrative has switched focus to creating the next social media app. As educators of low socioeconomic status youth en loco parentis we struggle to capacitate dreams which seem reserved for the affluent. The poignant truth is that invisible walls exist and continue to develop that ensure disadvantaged youth may never partake in that dream (post-ethnography discussion).*

East San José youth experience the consequences of social stratification, brownfield neglect, and housing that provides an indoor environment that is either too cold or too hot, one that is never right. Compounding these general inequities is that these youths live with a legacy of toxins left by sixty years of Silicon Valley industry development (Pimentel, 2004). Silicon

Valley has the highest concentration of Environmental Protection Agency (EPA) designated Superfund sites in the country (Schlanger, 2017). These sites are situated in communities of our students' demographic; "populations that are poorer, less educated, rent, are linguistically isolated, and predominantly Hispanic" (Stewart et al., 2014). When Tarantino et al. (2016) recognize with Krieger and Higgins (2002) that "homes of people with low income are more likely to be too warm or too cool because they are less well insulated, often have relatively expensive forms of heating such as electric baseboards, and frequently lack air conditioning," and that, "occupants often cannot afford to pay for the energy needed to make their homes comfortable," they recognize the students' reality.

> *The tech industry's physical boundaries are evident in the East Side youths' environment, juxtaposed by the community's socio-economic boundaries. Eventually, my students will realize they are on society's margins and within an industry that fails to provide adequate means for their social mobility. This is the crucial point where students can become agents of change for their future and their environment (field notes, post-ethnography discussion).*

Youth are "drawn to the social justice work because of their desires—perhaps in some cases tied to their families' desires for them—to learn to be in the world as a person from a marginalized race, gender, sexual orientation, or any intersection of these" (Akiva et al., 2017). Asset-based intersecting identities are corroborated by (Jacob et al., 2022). As K–12 career technical educators and civil and environmental engineering researchers working in the Silicon Valley spirit of innovation, this study furthers the development of an educational platform that aims to disrupt the trend of marginalization. As conceived by Tarantino et al. (2016), this platform aims to provide students with technologies and education to remediate their reality.

What are the sustainability challenges in Silicon Valley? This paper has explored equity, access to opportunity, and environmental justice relating to energy efficiency in the home and

environmental contamination outside the home. This paper has shown that a sustainable education curriculum as a construction technology course in an affluent region like Silicon Valley influenced student perceptions of sustainability and social mobility. However, as Benavot (2014) noted, this course operates within an ongoing struggle against a Silicon Valley culture of an overburdened curriculum that prioritizes exam topics.

Conclusion

This study recommends that secondary educators adopt a project-based learning method and begin teaching Virtual Design and Construction as part of the secondary education construction technology curriculum. In particular, we encourage both public and private schools to adopt a PBL-VDC curriculum with an emphasis on disrupting gender norms and attracting young women to a trade-based pathway to stack credentials and pursue a university education. This study recommends that public policymakers provide funding for such education and pass resolutions that encourage this education. Through such education, underrepresented youth not only have the opportunity to recognize the building industry as a pathway to prosperity, but they also develop a critical hope in social mobility, which generates solidarity, social action, and healing, key components for closing the achievement gap (Duncan-Andrade, 2009).

This research used a project-based learning pilot case of safe routes for pedestrian travel. This topic was selected for its environmental justice aspects and the practical need for a fail-safe topic (sidewalks are everywhere). As our VDC-PBL curriculum development gains confidence and capacity from pilots, the ambitious Energy Efficiency and Sustainability (EES) curriculum developed by Montoya et al. (2020) will form a new advanced virtual design and construction technology course.

Limitations

Progress in this research has not been without limitations. The VDC pilot course focused on a single high school, and the curriculum developed by Montoya et al. (2021) anticipated a pilot with three high schools. The pilot's limited scope has limited the sample size, which limits the generality of our conclusions. Our pilot group is also all-male, which further limits our findings. In parallel to this study are ongoing preparations to continue this research. In future research, the authors will investigate whether a learner-centered VDC-PBL intervention can help to break down hegemonic masculinity barriers in secondary STEM-CTE classrooms.

Study Three - Breaking Down Hegemonic Masculinity in CTE Classrooms

Research Question

1. Can a learner-centered Virtual Design and Construction Project-Based Learning (VDC-PBL) intervention help break down hegemonic masculinity barriers in secondary STEM-CTE classrooms?

Methods

Participants

The study draws on students from four high schools and two community colleges. The intervention cohort comprises 43 students, 11 of whom are female. Three students were selected as case study students for further inquiry. These three students represent the diversity of backgrounds and perspectives of the broader group. These three case study students were chosen because they represented the various compounding marginalizations or intersectional identities (Collins, 2008; Crenshaw, 1991; hooks, 2015; Jacob et al., 2022) of the schools and their pathways. Our students range from freshmen to seniors and are 15 to 18 years old. Twenty-three percent identify as female (approximately eight female students in a section of 35 students). Each cohort is made up of 14 unique course sections and in total contains approximately 150 students. The population is predominantly Latiné (50 percent) and Asian (40 percent). The students reside in a lower-income working-class community: 50 percent of students qualify for free and reduced-price meals, compared to 10 percent of students in a more affluent neighboring district. The academic performance of this population is neither under nor overachieving: it is at 90 percent of the metropolitan mean, 80 percent of an affluent district, and surpasses the performance of some outlying underperforming districts (Ed-Data, 2020). The region is

industrial, and its working communities suffer from a legacy of contaminants from industrial sites (Pimentel, 2004; Schlanger, 2017; Stewart et al., 2014). Despite the racialized socially and environmentally unjust reality they live in, the students are a well-performing and distinctly working-class demographic.

Data is also drawn from the 60 mentors in the program. The mentor demographics are diverse. A full third are women, compared to the typical underrepresentation of 3.5 percent women in the industry at large. Most mentors are educators (38 percent) and tradespeople (31 percent) though industry business partners were heavily recruited (15 percent), along with educator program alumni (16 percent). The racial/ethnic demographics somewhat represent the student population, though white mentors are overrepresented at 46 percent compared to the less than 5 percent white student participants. The representation of Asian mentors is on par with the student demographics (31 percent), while Latinx mentors are relatively underrepresented (15 percent). Finally, 8 percent of our mentors are Black compared to 2 percent of the students served. The regional demographic for women in construction is comparable: 31 percent white, 38 percent Asian, 26 percent Latina, and 2 percent Black (Office of Women's Policy, 2018). However, the student demographic shifts nearly completely to an equal ratio of Latina and Asian students. The mentors represent typical roles in the construction industry: technologists, construction managers, workforce educators, lawyers, policymakers, union labor leaders, social justice champions (such as labor leader Josué García and social equity researcher Dr. Anthony Kinslow II), civil engineers, and tradespeople.

Setting

This research relies on an ethnographic action research method (Hartmann et al., 2009) to better understand, from a grounded perspective, the limited role of women in construction and the effects of underrepresentation through the creation of a woman-centered CTE. This research does not try to fit an objective ideal of an imagined perfect reality to observations. Rather, I seek to understand a pragmatic reality, then explain that reality and apply the explanation in a useful way (Bernstein, 2016). As described in the previous section, the VDC workforce curriculum is implemented in a real-world setting within the VDC-themed STEM skills course. This course platform has hosted numerous research projects over the past twenty-five years, such as the role of multiculturalism in successful teamwork (Frank & Fruchter, 2014) and the role of indoor CO_2 levels on building occupant well-being (Grey & Fruchter, 2017). The PBL-VDC course provides a testbed for research. Our intervention relies on an RPP (Ahn et al., 2019; Gutiérrez & Penuel, 2014) that intentionally builds on the unique community setting that includes strong trade unions that are invested in the diversification and career advancement of the construction workforce, community organizations dedicated to the recruitment and promotion of women in traditionally male-dominated fields, and educational institutions willing to collaborate and partner across the K–12 and postsecondary sectors to promote college and career readiness of youth from historically marginalized communities.

Research-Practice Partnership

This study relied on a Silicon Valley-based RPP in Northern California that engaged many participants from the construction industry and local community. This RPP collaboration allows for a dynamic response to contemporary problems of educational practice (Ahn et al., 2019; Gutiérrez & Penuel, 2014). Our partnership included educators and other community

participants (i.e., union leadership, policymakers, and business partners). A dozen educators at the secondary and postsecondary partner institutions participated, ten of whom attended the 2018–2019 Summer VDC Introduction Professional Development training and six of whom completed the program and received its certificate. Figure 1 depicts the numerous organizations that make up our RPP and together are known as the Santa Clara County Construction Careers Association (S4CA). Our partnership included four high schools, three community colleges (i.e., 2-year colleges), eight apprenticeship programs, an adult education program, and two universities (i.e., graduate and bachelor's degree-granting institutions).

Each participant group supports the S4CA mission of preparing youth for construction industry careers by relying on their unique expertise. The educators are responsible for adapting the VDC curriculum for our focal population, directing focus topics, helping to explicate the students' lived experience, and leading the CTE courses. Our community partners include over one hundred leaders in education, labor unions, legislators, public sector administrators (i.e., policymakers), and construction businesses. Community partner organization members serve in mentoring roles for student participants in addition to providing job and union placement services. A crucial partner for this model is the county-level council of building trades labor unions. The Santa Clara County Building Trades Council has a long-standing relationship with construction business signatories to labor union agreements, is knowledgeable of the public prevailing wage infrastructure dictated by the labor agreements, and is composed of key stakeholders of the unionized workforce that is educated via the secondary and post-secondary education infrastructure. Every three months over the course of six years, the community participants met for community input and reflection, collaboration, and planning the next steps to guide the career pathway planning. This research is one part of this larger partnership, and the

formal ethnography spans several years (2017–present) and draws on several hundred hours of participant observation over that time. This paper focused on the year that the project was more directly focused on recruiting female mentors (2018–2019), and the data drawn on over this year is described below in the next section, Sources of Data.

Sources of Data

Data was collected in three settings: the high school classroom, the university presentation space (CIFE), and virtual presence (Zoom). The case study students are from West Mendez and Big Piper high schools. Students had both a virtual presence via Zoom and an in-person presence in different high school classrooms and CIFE at Stanford.

The university presentations were a series of two-day events in which students from several high schools and multiple school districts were bussed to the CIFE lab at Stanford. The first in-person event is a Building Information Modeling (BIM) bootcamp where students are taught BIM software by Stanford faculty (September 15–16). The students at the BIM bootcamp also participate in campus tours, guest lectures, and fun activities with Stanford graduate students. The second in-person event was the dry-run presentation (April 23–24), where the students returned to CIFE to present their projects and receive critical feedback. This presentation included the same participants and mentors from S4CA, as well as other university mentors. The final presentation event (May 21–22) also takes place at CIFE with the same participants, including S4CA and university mentor feedback. This event also includes district leadership from various schools, as well as other policymakers.

The virtual events were held on Zoom, during which student teams gave presentations. Students were physically in several locations. The mentors included members from S4CA and various university mentors. Each event focused on critical feedback. This includes the team

check-in (November 24–25), project critiques (January 28–29), and the winter project cyber (February 25–26), in which students presented virtually and received mentor feedback.

The researchers participated in high school classes, post-secondary classes, dual enrollment observations, university presentations, virtual events, informal interviews, and various meetings with the RPP to collect and analyze data for this paper. Each of these individual categories is described in detail below, but see Table 4 for an overview of the total data collected in this project and Table 5 for an overview of the VDC events.

Procedure

The practitioners recorded the high school classroom through daily field notes and ethnographic narratives, while the virtual and university presentations were video/audio recorded. There is overlap in data collection in many cases due to students, mentors, and researchers being in several different physical locations while also participating synchronously in virtual sessions. The case study students are from West Mendez and Big Piper high schools. The practitioners interacted with case study students virtually and in person in different high school classrooms and at CIFE.

Measures

Inductive coding was used to identify barriers due to hegemonic masculinity and instances of overcoming these barriers. Data from student artifacts, including photos, audio, video, transcripts of student presentations, student and mentor interactions, and slides of student presentations at each stage of their project were coded under these broad categories, with sub-codes being generated.

Table 4

Sources of Data

Data Source	Overall	Focused on 3 case study students
High school class observation/field notes	182 days of practitioner field notes	30 researcher visits
Postsecondary observations	100 hrs	
Dual enrollment course hours	50 hrs	25 hrs
Presentation videos	40 hrs	10 hrs
Presentation slide decks	25 presentations	10 presentations
Informal interviews	20 interviews	10 interviews
S4CA skills-fair projects	90 projects	3 projects
Researcher meetings	40	
Teacher meetings field notes	10	
S4CA meetings field notes	4	
Apprenticeship coordinators meetings field notes	4	

Table 5

Workforce Virtual Design and Construction events

Event	Date	Primary Location	Number of Participants
Summer VDC Introduction Professional Development	July 27–31	CIFE	10 instructors
BIM Bootcamp	September 15–16	CIFE	43 students
Team Check-in (Problem Statement)	November 24–25	Virtual	39 students
Project Critiques with Industry	January 28–29	Virtual	37 students
Winter Project Cyber (Midterm)	February 25–26	Virtual	37 students
Dry-run Presentation	April 23–24	CIFE	37 students
S4CA Skills Fair	April 12th	IBEW Union Hall	15 VDC students 90 total Students
VDC Integration Experience	May 21–22	CIFE	
Student Final Presentations		CIFE	37 students
Instructor Final Presentations		CIFE	6 instructors

Using an ethnographic action research method (Hartmann et al., 2009) the authors leveraged their roles as instructors and researchers to gather various sources of data. The authors collected data using fieldnotes, audio/video recordings, student artifacts from presentations and projects, and narrative ethnographic notes. Data were collected in three settings: the high school classroom, the university presentation space (CIFE), and virtual presence (Zoom).

The High School Classroom

The high school classroom was recorded through daily fieldnotes and ethnographic narrative by the practitioner, while the virtual and university presentations were video/ audio recorded. In many cases there was overlap in data collection due to students, mentors, and researchers being in several different physical locations while also participating synchronously in virtual sessions. The case study students were from two different high schools. The practitioner interacted with case study students both in person and virtually in different high school classrooms, as well as both virtually and in person at CIFE.

University Presentations

The university presentations were a series of two-day events in which students from several high schools and multiple school districts were bussed to the CIFE lab at Stanford. Postsecondary students from community colleges and apprenticeship centers were also at these events, learning alongside the high school students. The first in-person event was a Building Information Modeling (BIM) bootcamp (Figure 10), where students were taught BIM software by Stanford faculty (September 15–16). The students at the BIM bootcamp also participated in campus tours (Figure 13), guest lectures (Figure 14), and fun activities (Figure 15) with Stanford graduate students. The second in-person event was the Dry-run presentation (Figure 16) (April 23–24), where the students returned to CIFE to present their projects and receive critical feedback. This presentation included the same participants and mentors from S4CA and other university mentors. The final presentation event (Figure 17) (May 21–22) also took place at CIFE with the same participants, including S4CA and university mentor feedback. This event also includes district leadership from various schools, as well as other policymakers.

Figure 13

Students visit the Product Realization Lab with Dan Somen

Note. The Product Realization Lab is one of the many shops that look very similar to the traditional wood shops at the students' schools. Photo Montoya

Figure 14

Stanford graduate student mentor Alyssa Cooperman gives an engineering lecture.

Note. The students attended several lectures at CIFE led by female mentors and graduate students. This is the same room in which students will give their dry-run and final presentations. Photo Montoya

Figure 15

Stanford tour guide gives directions for a scavenger hunt

Note. Through activities, the students become familiar with the campus. Photo Montoya

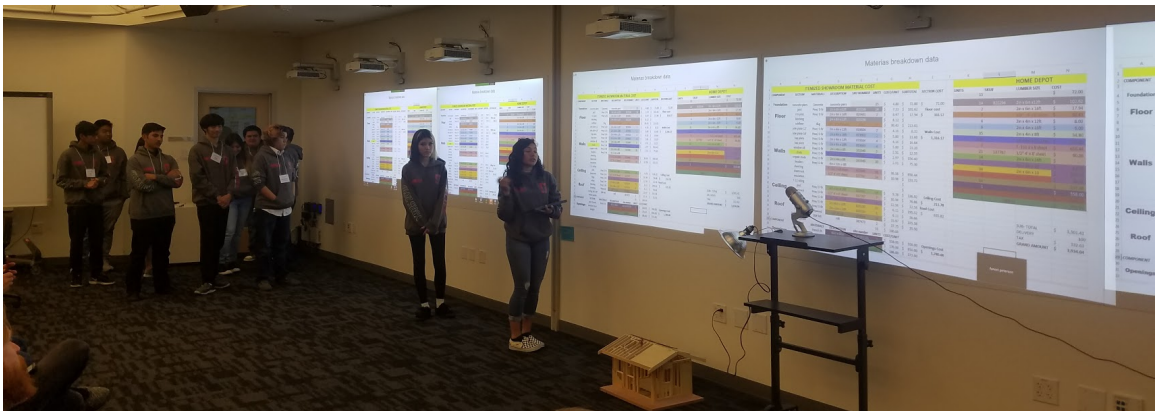
Figure 16

Dry-run presentation at the Center for Integrated Facility Engineering

Note. At the March Dry-run presentations, two months prior to final presentations, students are looking at their presentation slides. Photo Montoya

Figure 17

Angelique and Anahí lead their team in the final presentation.



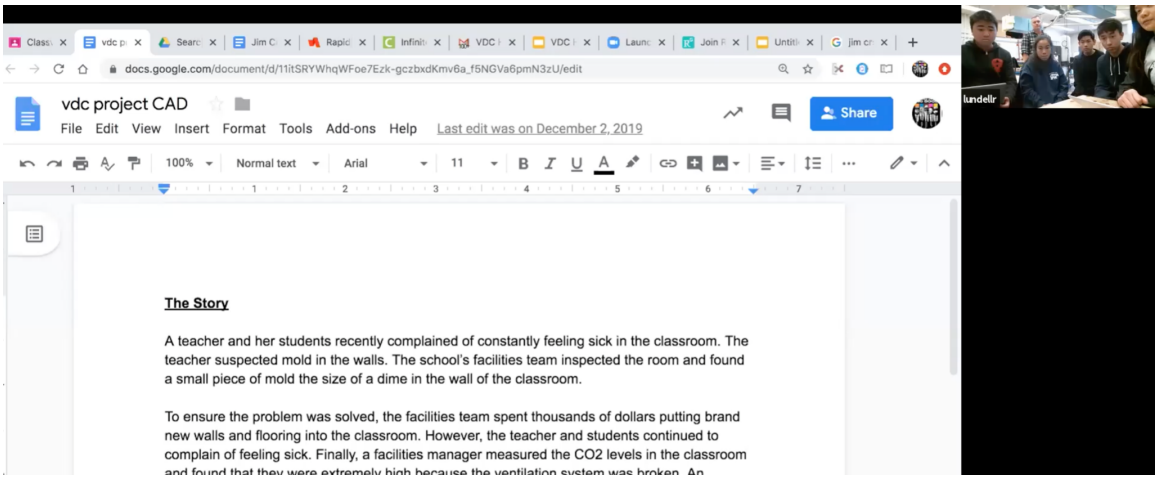
Note. After two more months of project development and virtual mentoring calls, the students return for a May final presentation. The presentation, social, and technical skills are now equivalent to the university level. Photo Montoya

Virtual Events

The virtual events were each held on Zoom, during which student teams gave presentations. Students were physically in several locations—typically their schools, but some students participated from other locations such as workplaces or their homes. The mentors included members from S4CA and various university mentors. Each event focused on critical feedback. These included the Team check-in (Figure 2) (November 24–25), Project critiques (Figure 4) (January 28–29), and Winter project cyber (Figure 18) (February 25–26), in which students presented virtually and received mentor feedback.

Figure 18

Emily's team presents virtually for winter project cyber



Note. Emily and her team presented their project for feedback to further iterate their project and presentation. Photo Montoya

Informal Interviews

The researcher and practitioner conducted several informal interviews (Figure 19) with a dozen colleague researchers and practitioners who are all part of the broader RPP and ethnography. These informal interviews took place during and after events and planning sessions. The researchers used these interviews to gather data around student and practitioner experience which was not captured during formal events and mentoring sessions. The researchers also used these informal meetings to discuss curriculum and do member checks and logic checks for interpretation of data analyses.

Figure 19

Researcher meets with mentor and journeywoman pipefitter Aster for an interview

Note. The researchers met with Aster often to discuss her expertise on workforce education. (Montoya et al., 2021)

Analysis

***(RQ)* Can a learner-centered Virtual Design and Construction Project-Based Learning (VDC-PBL) intervention help break down hegemonic masculinity barriers in secondary STEM-CTE classrooms?** This question was addressed through ethnographic participatory roles (i.e., as mentor and instructor), and data was analyzed using inductive coding to identify key themes in student artifacts, including photos, audio, video, transcripts of student presentations, student-mentor interactions, and slides of student presentations at each stage of their project. Codes were theoretically grounded in hegemonic masculinity theory (Connell & Messerschmidt, 2002) and used as a lens to see and interpret these data for instances of barriers as a result of hegemonic masculinity and instances of overcoming these barriers. As part of a larger research team, over one thousand slides and over one hundred hours of student

presentation videos with mentor feedback were analyzed. Student teams each turned in five versions of their developing presentations. I choose five teams from five different schools to analyze their artifacts further (*n = 25*). I chose two additional teams (*n = 10*) to draw three case study students and further analyzed their artifacts. These artifacts were analyzed and coded before and after student presentations by the researcher practitioner team. The research team met at regular intervals throughout the course to discuss emerging codes, trends, and themes. To structure student presentation artifacts, we focused on the research question: **Can a learner-centered Virtual Design and Construction Project-Based Learning (VDC-PBL) intervention help to break down the barriers of hegemonic masculinity in secondary STEM-CTE classrooms?** Using this question as a guide we worked to identify barriers and instances of perseverance.

At the conclusion of each event and at each milestone event (i.e., BIM Bootcamp, project critiques, dry-run, and May final), researchers compared their observations and field notes to frame artifacts and discuss their potential meaning to determine findings. The team met weekly to interpret and discuss findings. Following earlier examples of classroom ethnography, the analysis was interpretive and grounded in narrative data (Strauss & Corbin, 1994). As observations of experiment interventions showed an evolving narrative, our outcomes and themes evolved iteratively.

Through ethnographic participatory roles (i.e., as mentors and instructors), the authors analyzed and used inductive coding to identify key themes in student artifacts, including photos, audio, video, transcripts of student presentations, student and mentor interactions, and slides of student presentations at each stage of their project. These data are composed of 2,350 files, which

take up 133 GB of storage. We examined over one thousand slides and over one hundred hours of student presentation videos with mentor feedback. Student teams each turned in five versions of their developing presentations. We chose five teams from five different schools to analyze artifacts further (*n= 25*). We chose an additional two teams (*n=10*) from the feminist intervention case study students. These artifacts were analyzed before and after student presentations by the researchers and practitioners. The authors met at regular intervals throughout the course to discuss emerging trends and themes. To structure student presentation artifacts, we focused on identifying instances of student engagement, relying on Fruchter's PBL engagement metrics: engagement, disengagement, side conversation, gaze foci, and use of technological tools (2007). Harder-to-observe indicators such as gaze foci were captured using body-language feedback by the researchers individually and later confirmed as a group. Fruchter's engagement metrics provide indicators (superficial versus real opportunities) of the result of the intervention (feminization of the workforce education model) on the opportunity gap.

At the conclusion of each event and at each of the milestone events (i.e., BIM Bootcamp, project critiques, dry-run, and May final), the authors compared the observations to frame artifacts and discussed their potential meaning to determine our findings. The researchers met weekly to interpret and discuss findings, and met monthly with the practitioners to solicit feedback on our interpretation of the aforementioned artifacts and engagement metrics. Following earlier examples of classroom ethnography, the analysis was interpretive and grounded in the narrative data (Strauss & Corbin, 1994). As observations of experiment interventions showed an evolving narrative, our potential theory outcomes and emergent themes evolved iteratively. As this is an ongoing ethnography to iteratively improve this curriculum and pathway, the

observations and discussions have been compiled as a series of reports (Tarantino et al., 2016; Montoya et al., 2018; Montoya et al., 2020).

Trustworthiness

In order to ensure trustworthiness, the authors followed the lead of Mustaffa (2018) and adhered to Lincoln and Guba's (2006) four measures of trustworthiness: credibility, transferability, dependability, and confirmability. ***Credibility*** is considered with our choosing of participants, described above. The participants are the only ones who can truly tell their own stories (Mustaffa, 2018 p. 252). We completed member checks with all our participants, and additionally logic checks with key stakeholders. For example, we regularly held feedback sessions with S4CA mentors, where we discussed initial findings. One such discussion with dedicated academics of feminism, which developed during feedback, questioned whether the lack of women in construction fields is due to choice or gatekeeping: do women simply choose not to join the trades, or is there a set of systemic barriers that prevent women from joining and remaining in the trades? To address this question, a fifth-term union apprentice in the pipe trades shared her experiences (apprentices have five terms of education before reaching journey skill level). She has not experienced gender discrimination in her time as a tradeswoman within the San José metropolitan region—in fact, her experience is the opposite. On the other hand, we did hear feedback that a transfeminine individual faced gender-based discrimination in this region. The apprentice we spoke with did say she hears firsthand from tradeswomen in other metropolitan regions around the country who experience severe gender discrimination. If her gender-neutral experience is representative of the region, then the young women in the Workforce VDC program should find a clear gender-neutral pathway from secondary education, through post-secondary pre-apprenticeship, and on to an apprenticeship. Regular discussions

with mentors along these lines allow us to ensure that we were genuinely representing the experiences of our students. ***Transferability*** "refers to the researcher thoroughly explaining the study's context and their underlying assumptions for outside researchers or readers to determine the extent to which they can transfer or use findings" (Mustaffa, 2018 p. 253). To adhere to this principle, the authors explained the participants, collaborations, and curricula in great detail. We understand that our situation and region are unique, and feel that we have provided sufficient detail and context to best facilitate transferability. "***Dependability*** refers to the record that shows the research process that led to the findings and ***confirmability*** refers to the process used to consider alternative or divergent evidence and explanations" (Mustaffa, 2018 p. 253). Our description of our ethnographic methods and sources of data in prior sections shows the dependability of our methodology. The confirmability is strengthened by multiple sources of data, and our interactive process of coding and meeting to discuss emerging themes and alternative explanations. Further, our member checks and discussions help to confirm our findings, which will be discussed in the next section. Now we turn to describe the case study students.

Results

Introducing Case Study Students

Introducing Anahí.

Anahí was a senior at Yerba Buena high school during this study, and graduated a few weeks after her VDC final presentation. Anahí started the construction technology pathway at her school during her freshman year, and remained in the program until her graduation. During her time in this pathway, she participated in the S4CA skills competition during her sophomore year, where she and her teammates placed first overall. Her instructor's comments on her winning project are below.

> *"Their project was a contraption that secured doors in classrooms [for lockdown drills]. During the drill that took place that year, SJPD compliance officers stated that these are the best locking devices they have seen in all their years of locking compliance checks."*
>
> *—Construction instructor*

During her senior year, Anahí was also a student aid for a lower level construction class, where she worked to help other students with their projects and tools. Anahí was instrumental in her VDC project team: she was a great motivator, leader, and team player. Aside from excelling in academics, Anahí was also working at a local movie theater during her senior year. Often her work schedule was in conflict with VDC project presentations. Anahí showed her professionalism and team spirit regarding schedule conflict dilemmas. On one occasion Anahí was determined to present at Stanford in person, but did not own a car, so directly after her presentation she hired an Uber rideshare in order to be back at work in time for her shift. After graduating, Anahí made time to give invited presentations at an S4CA meeting and also at the

school's District Office regarding the VDC team's experience. Anahí enrolled in a local community college (Fiddlers' Green College) after graduation.

Introducing Angelique

Angelique and Anahí were teammates on their school's soccer team. Angelique was a senior during this study and also graduated a few weeks after her final VDC presentation. Her instructor describes her by saying that, "Her focus and collaboration were outstanding."

Angelique volunteered several times to participate in VDC-related activities including presentations and project building, which required a significant time commitment beyond her normal class schedule. Angelique was so proud and enthusiastic about her hands-on projects in her construction class that during her dual-enrolled summer VDC session with Fiddlers' Green Community College, she invited her father to the classroom in order to show him the projects she had worked on. She walked her father to different projects she completed and explained to him what they were and specifically what she did on each project. Angelique also volunteered to present at S4CA and the District Office. Angelique's chosen role on her VDC project was financial analyst, and she also entered her VDC project component into the skills fair competition and won the (1) Laborers award, (2) McCarthy award, and (3) High School Creativity award. Angelique also enrolled at the local community college (Fiddlers' Green College) after graduation.

Introducing Emily

Emily was a junior at Piedmont Hills high school during the focus of this study, but continued on another year as a team steward. Her junior year was the first year she was involved in the VDC program. During her time in high school, she enrolled in nearly all available advanced placement (AP) classes and played badminton while taking the lead role in her VDC projects. Like Angelique, Emily had a few presentation conflicts arise around sports schedules and her AP exams. During her final VDC presentation, she completed an AP computer science exam immediately prior to giving her final presentation at Stanford. Her parents were able to give her a ride so she could make both events. Her instructor comments on her as a student below:

> *"I had countless conversations with other teachers, professors, and professionals about her rare combination of discipline, humility, and creativity. Simply put, everyone agreed that Emily was a star."*
>
> *—VDC Instructor*

Emily and her VDC team worked with mentors to design a conceptual Tiny Home community for the homeless to help alleviate the Bay Area housing crisis. Not only did she survey land for construction feasibility, but she also interviewed representatives from non-profit organizations that represent the homeless to learn more about the needs of the community. Emily guided her team to create a virtual design for a "high-performing" classroom to combat CO_2 accumulation. She went on to major in Civil Engineering at UC Berkeley.

Overview of Findings

Using an ethnographic action research method, the authors observed three case study students over the course of one academic year. The authors used participant observation, student projects, and informal interviews to document and witness the students' everyday realities in these male-dominated spaces. Through collecting artifacts and observations, the authors were able to recognize the existence of specific barriers to female participation in STEM-CTE pathways and careers. With the recognition of these sociocultural realities as a lens, the authors also observed several situations in which these young women were empowered to overcome these barriers to not only achieve full equitable inclusion in these pathways, but to emerge as leaders and exemplars of STEM-CTE students. The authors noted that these gains in equitable participation were achieved through the implementation of a learner-centered and feminist environment in which the young women took ownership of their Virtual Design and Construction (VDC), learning through group projects and interactions with a variety of construction industry actors. Lastly, the authors observed and documented a change in gender role perceptions, and found evidence that young women have a greater interest in and understanding of workplace safety, environmental protection, social justice, and labor standards.

Recognizing the Existence of Barriers to Female Participation

During the BIM bootcamp at the start of the program, Angelique explained to the researchers that she did not feel that her father's workplace could include her. Fast forward to the question and answer portion of the final presentation (Figure 17), and Angelique explained to the mentors and researchers that she could now see a role for herself at her father's place of employment: a construction site. This suggests that the Workforce VDC program provided

Angelique and the other case study students with the opportunity to feel like they belong in the construction industry. When Angelique first arrived in the construction class at her high school, there were only 3 percent young women in that course. Visiting the woodshop at Stanford (Figure 8) and seeing over 50 percent women working on projects inspired her to continue in this industry. After completing this course, Angelique enrolled in a dual enrollment summer course at her high school. Anahí was also inspired to complete projects and continue in the industry. Competing in the traditionally all-male skills fair, Anahí entered the model she built (Figure 20) for her project, as well as the cost estimating spreadsheet to go along with it. She won awards for both. For the final presentation she took this further, and led her team to create a BIM using REVIT (Figure 21).

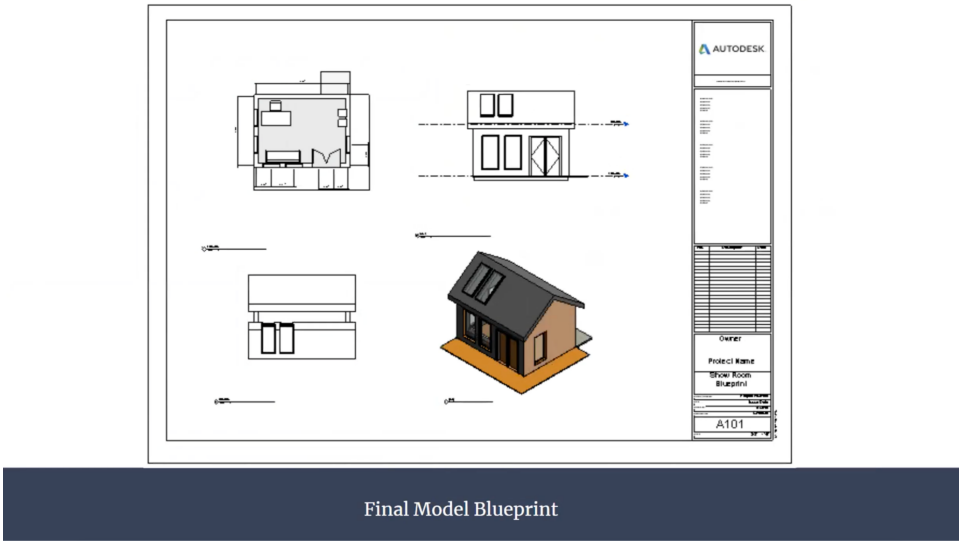
Figure 20

Anahí and her construction instructor display her model and cost spreadsheet for skills fair

Note. The skills fair typically focuses on built projects, which Anahí completed with a model. Photo Montoya

Figure 21

Screenshot of BIM using REVIT for Anahí's model.



Final Model Blueprint

Note. Anahí also modeled with BIM, and created a spreadsheet. She won awards for both. Screenshot Montoya

Overcoming Barriers to Participation

Confidence was a recurring theme throughout our research. Emily took on a leadership role on a team of four young men. Under her leadership, they developed a study of homelessness in Silicon Valley (see Figure 22).

Figure 22

Final student presentation at the Center for Integrated Facility Engineering

Note. Photo Montoya

Guided by Emily, this team embraced social justice topics such as homelessness. Using approaches and technology tools from traditional construction problems, these students have reimagined the field of construction and learned those skills through an alternative narrative.

Emily took the lead to schedule a meeting with community stakeholders and nonprofits who serve homeless communities, where they were able to discuss the overall needs of the homeless in Silicon Valley. Figure 23 shows a meeting Emily set up with the various stakeholders at a local pizza shop.

Figure 23

Meeting with community stakeholders and nonprofits who serve homeless in Silicon Valley

Note. Emily and her team invited local stakeholders and nonprofits to help her team better understand the needs of those affected by homelessness. Photo Montoya

In interviews with Emily's VDC instructor, he often discussed how impressed he was with her initiative and leadership. Below is a quote from our fieldnotes in which he discusses the meeting depicted in Figure 24.

> *"Emily and her VDC team worked with mentors to design a conceptual Tiny Home community for the homeless to help alleviate the Bay Area housing crisis. Not only did she survey land for construction feasibility, but she also interviewed representatives from non-profit organizations that represent the homeless to learn more about the needs of the community."*
>
> *—VDC Instructor, 2020*

The team then proposed an affordable housing solution that included designs both for individuals and different sized families. Emily and her team used community input to design

their housing units and their community of housing units. Figure 24 is a screenshot of the three different tiny home designs the team came up with for different family sizes and types.

Figure 24

Screenshot of student presentation slides with three different tiny home designs.

Note. The tiny home team displays the three different designs they created with feedback from various community stakeholders and mentors.

The scope of this project was to design a building using BIM programs such as REVIT. Emiliy went above and beyond when she spearheaded reaching out to community stakeholders. Her leadership was crucial to this team's success. The following quote is taken from fieldnotes where her VDC instructor explained the extent of her leadership role:

> *"For the last two years, due to their extraordinary resilience and creativity, our female VDC students have become the de facto leaders for their teams. Without a doubt, the entire team looked to them to set the pace for the entire project. In fact, Emily is consistently referred to by her team as 'our fearless leader.' "*
>
> *—VDC Instructor, 2020*

It was during this experience that Emily approached the program lecturers and asked for a letter of recommendation to accompany her university application. Through the program, she had discovered that there were opportunities for her in public infrastructure professions, and she had decided to apply for the UC Berkeley (Cal) and Massachusetts Institute of Technology (MIT) Civil Engineering degree programs. (She currently attends Cal, which at the writing of this paper is ranked first in the country in Civil Engineering). At the beginning of the program Emily explained to her instructor and mentors that she was planning to major in computer science. Through observing Emily's interaction with her team and mentors we watched her choice of major change after her second cohort of the Workforce VDC program, where she had continued with the program as a team steward. The following excerpt is from the teacher fieldnotes where her instructor describes the leadership role in VDC.

> *"So not only has VDC allowed our female students to develop their leadership skills, but it also gives them numerous opportunities to meet and be directly mentored by industry professionals who are also female. In the end, one of the greatest benefits I've found with VDC is that it shatters the 'glass ceiling' and shows our female students what opportunities are open to them in the future. What other High School class can come close to offering this? In a decade of teaching, I have yet to find one."*
> *—VDC Instructor, 2020*

The following quote comes from an email Emiliy sent to her VDC instructor.

"Thank you for being our VDC mentor! VDC has been a very important part of my high school experience, and it's a big factor that helped me choose Civil Engineering as my major. From Tiny Homes to CO_2, VDC has made me more knowledgeable about the world and issues that impact our very own community. This year's project has reached heights I would have never imagined. It's still unbelievable that we were featured on NBC news and invited by the Vice Mayor of Sunnyvale to present! None of this would have been possible without your guidance and leadership. Thank you again for putting so much time and effort into making our project a success!"

—Emily, 2020

When we discuss women in the construction education system, we are drawing on the experience of Emily, Anahí, Angelique and all the other young women in our VDC program. The students can take engineering as far as they would like, and the VDC program will always provide mentors to support their paths into engineering. Students have access to mentors both as individual teams and when they present their project to the virtual panel of mentors. For example, Anahí took an interest in electrical calculations and by the conclusion of her project, she had advanced beyond the remaining casual knowledge on the topic by the civil engineers in the room. Although the program is intended to be rigorous, it is specifically designed to avoid the masculine gatekeeping that can be present in other engineering programs, and the experiences of Emily, Anahí, and Angelique show the effect that this design has had.

A Novel Model for Creating a Feminized Space

Anahí's group worked as a team, but she did comment to the investigators that there was a difference in expectations for young men versus young women. Despite feeling this difference

in expectations, Anahí took on her chosen role of financial analyst and used a spreadsheet software to develop a cost estimating tool, and then turned their estimate format into a reusable program based on equations. The authors noted that this was unique because the assignment was simply to calculate the cost of their team's proposed social justice mitigation plan, and neither a spreadsheet nor equations were part of the assignment rubric. During the project critiques, Anahí's group asked mentors for advice, and then took the initiative to develop a solution to the problem they were presented with. With the support of the mentors and their teammates, Anahí's group had the confidence to create something unique in a field they otherwise did not see themselves participating in equitably. Their work was excellent, surpassing even some of the coursework produced by post-secondary students. Their use of spreadsheet coding and the ability to format the spreadsheet into a coherent layout is not universal in the civil engineering field. Anahí's group was confident in their footing in technical topics alongside their male peers.

Social Justice and Environmental Awareness

While teaching numerous construction courses over the past decade, the authors have observed that the young women in the Workforce VDC program showed greater sensitivity to and readily accepted issues of social justice and the environment as problem topics. Emily's team went above and beyond to delve deep into the homelessness problem in Silicon Valley. The students actually visited a homeless encampment with an unhoused individual they knew personally, and shared a video of this encampment in their presentation (Figure 25). The scope of the project was to design a home, but their depth was powerful. Because of their personal interview, they added environmental considerations to their tiny home design, including the need for a community center (Figure 26). These considerations that evolve from interactions with the affected community are often overlooked in pure design or engineering curricula.

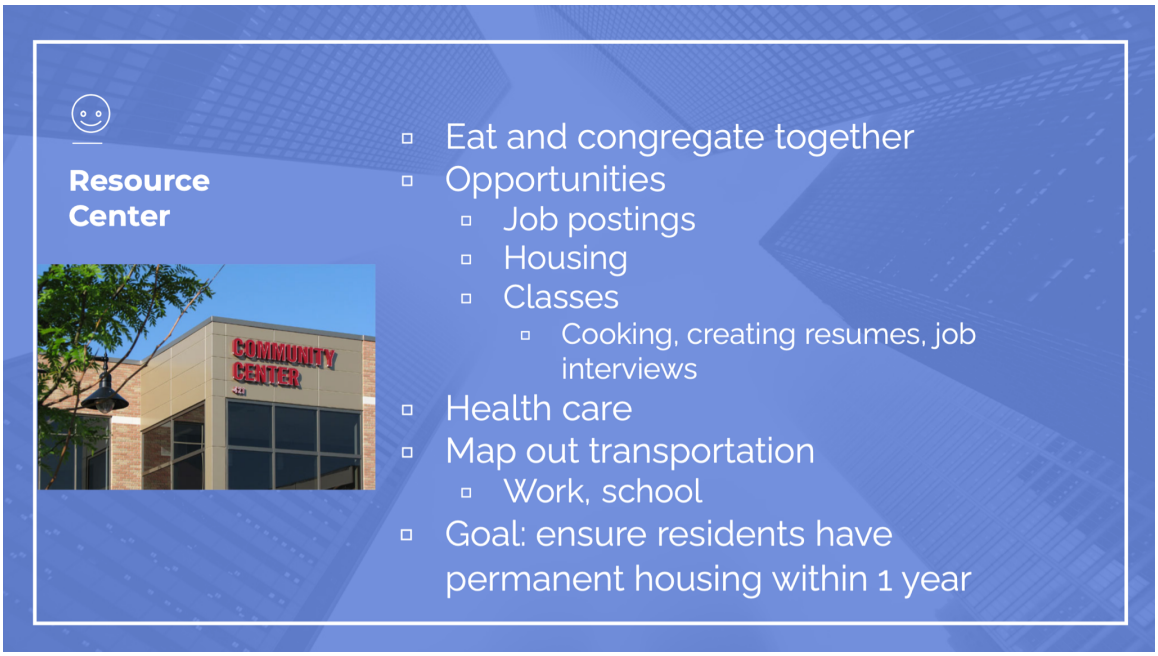
Figure 25

Screenshot of student interview video at homeless encampment

Note. This is a screenshot of a video where students interviewed an unhoused person they knew personally, and he brought the students into where he lives.

Figure 26

Screenshot of student presentation



Note. This is a screenshot of the students' presentation where they discuss the community center, close to where they proposed their tiny home site.

We observed a similar trend in Dr. Fruchter's Architectural-Engineering-Construction Global Teamwork course—young women often raise safety as a topic without prompting from instructors, whereas we have seen the opposite in groups of young men, where toxic masculinity perpetuates unsafe working conditions. Unsafe working conditions are often glamorized or boasted about as taking risks or doing what it takes to get the job done. These sentiments are personified in Figure 27: a slide of a post-secondary VDC team describing to mentors how they faced certain challenges with their project. They pre-built a wall and, upon realizing they could not fit it in their door, decided to lift it over. The students glamorized these actions and mentors were unimpressed, but it provided a great learning opportunity for all students.

Figure 27

Dry-run presentation slide showing unsafe working conditions.

Note. This slide is from Fiddlers' Green College's VDC team, showing unsafe working conditions, where they were moving a wall into their structure.

Through observations while teaching these courses both in secondary and post-secondary classrooms, the authors have seen the perpetuation of hegemonic masculinity create very unsafe working conditions. These incidents were far less common in teams which included young women. The authors understand that gender and gender roles are very complex, and we are not attempting to oversimplify these concepts. However, when we compare the focus of the various teams, we see an affinity toward compassions and safety in teams that included women. Compassion for others is personified in the artifact below (Figure 28), where Emily's team took a photo of a tattered Polaroid that they found in the proposed tiny home site. Seeing this photo pop up in their presentation was moving because while visiting the proposed tiny home site, the

students came across some belongings left by a homeless man. They were touched by this experience. Out of respect for the unhoused individuals the students did not take their photos, but took photos of things on the ground. The authors remember this being a very powerful experience for all the students.

Figure 28

Slide from student presentation with a polaroid of a family taken near a homeless encampment

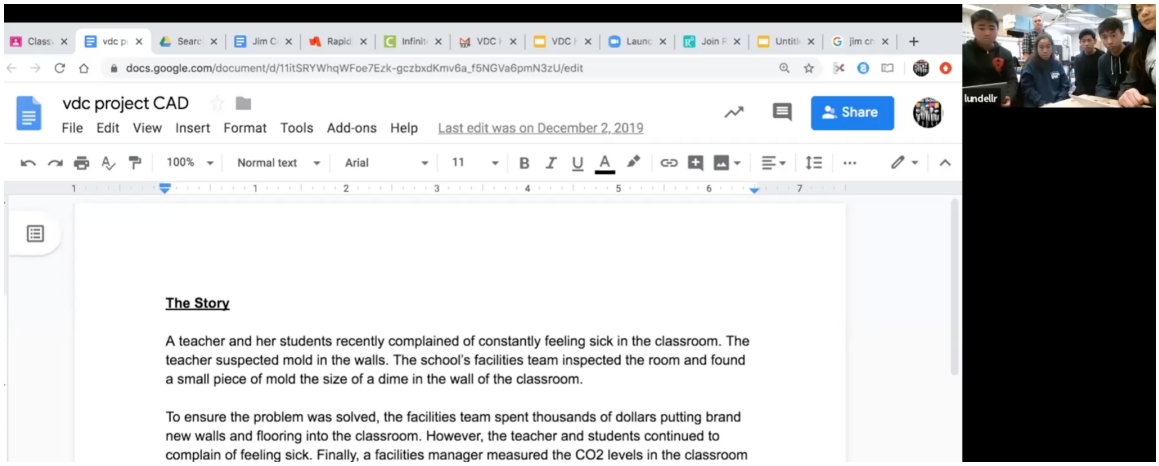
Guided by Emily, this team embraced social justice topics such as homelessness. Using approaches and technology tools from traditional construction problems, these students have reimagined the field of construction, thereby learning those skills through an alternative narrative.

This slide combined with our fieldnotes show that VDC students with more female participation also have more projects geared toward social justice concerns. These three young women will each continue in the construction industry on a pathway that will contribute to increasing the overall participation of women in the construction industry: see the progression of female confidence in Figure 16 (dry-run presentation), in Figure 30 (mentor feedback on

presentation and content), in Figure 17 (confident final presentation), and in Figure 31 (honored and recognized at a regional trades fair).

Figure 29

Winter cyber critiques



Note. At the Winter cyber critiques, students receive feedback from mentors.

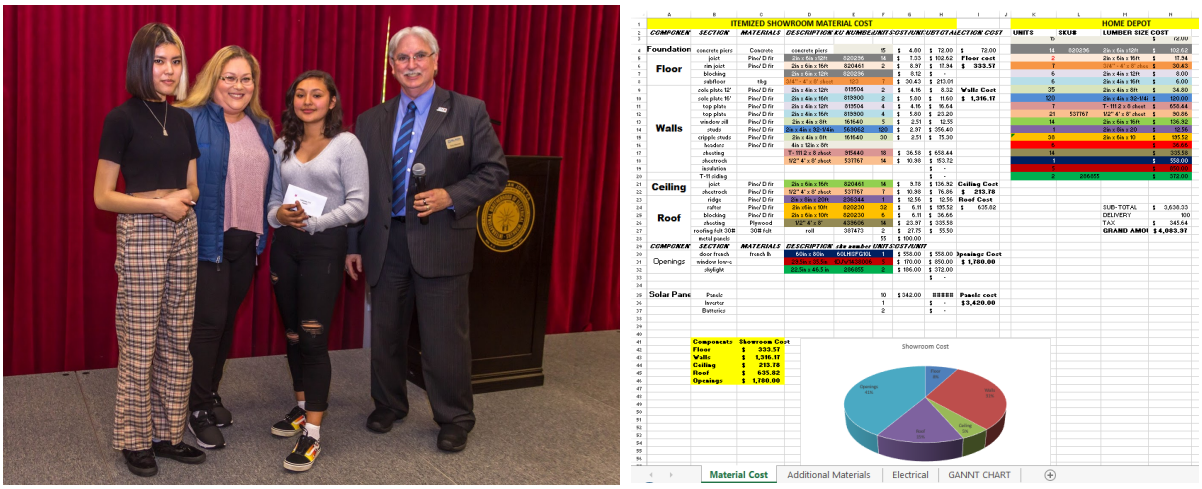
Figure 30

Mentor Feedback

Note. At the March Dry run, a diverse panel of mentors give feedback on presentation skills and construction technical details.

Figure 31

Student awards at International Brotherhood of Electrical Workers Union Hall



Note.The cost-estimating spreadsheet developed by Angelique s group. They received a construction skills fair award for their project, and in this picture are flanked by a business leader and a labor union representative—the event is held at a building trades labor union hall (IBEW).

Discussion

Our research contributes a feminist positive pathway to VDC theory through three theoretical modifications: (1) recognizing the existence of a barrier for female participation, (2) overcoming these barriers to participation, and (3) a novel model for creating a feminized space. The authors also uncovered that through increased female participation, VDC projects took on problems not just of the built environment but of social justice and environmental awareness. The authors successfully increased the participation of young women in STEM-CTE pathway courses, which lead to building industry careers.

Through this research we have identified the existence of barriers for young women entering high-skill, high-wage jobs in the construction industry. We recognized and documented young women's low participation in the STEM-CTE courses which are feeders to the labor force. Through informal interviews with students, we uncovered gendered messages these young women receive that result in the barriers to the high-skill, high-wage energy infrastructure industry occupations noted by (Montoya et al., 2020). We revealed that these messages also functioned to exclude these young women from perceiving social mobility for themselves in STEM-CTE occupations. Through analyzing observations and student presentations we also uncovered the blatant and latent hegemonic masculinity found in the STEM-CTE courses, as well as in the careers which these courses serve as pathways into. We documented the dearth of young women in these pathways, and revealed some of the sociocultural realities that (Bonilla, 2020) suggests are preventing these young women from entering traditionally male-dominated sectors such as civil and environmental engineering. We noted that recognizing these barriers is the first step to addressing the toxic masculinity and lack of female inclusion in this industry. The recognition of the existence of these barriers is crucial to dismantling them and advocating for more equitable access to this industry, and its occupations.

Using data from student observations and projects, we documented instances where these young women were able to overcome barriers to their participation and excel in their STEM-CTE courses. Through our case study student projects, presentations, and informal interviews we observed and documented the students' leadership development and project iteration over the course of their yearlong curriculum. Through analysis of presentation video, we were able to document increased engagement through the year using Fruchter's engagement metrics. The authors noted that within the learner-centered and feminist environment case study, students

became progressively more engaged throughout the year. Our evidence suggests that these gains in gender parity were made possible by the unique CTE experience which provided a feminist learner-centered environment. This environment allowed our young female participants to emerge as the leaders and champions of their VDC projects. In each of our case study projects, the young women took on leadership roles and their projects went above and beyond the requirements. In each case these students' dedication and innovation resulted in more opportunities and recognition in the form of project presentations and prizes, which resulted in increases in their perceptions of social mobility in these occupations as well as feelings of acceptance and belonging in these courses.

Equitable participation was achieved through the implementation of a novel curricular model which was learner-centered and provided a feminist environment in which the young women could take ownership of their Virtual Design and Construction (VDC) learning through group projects and interactions with a variety of construction industry actors. Our curricular model intentionally increased the number of female students and mentors to help combat the pervasively male-dominated environment of the building industry and its various careers. Through our observations and fieldnotes, we documented increased engagement and identification with this industry during the feminization of these spaces. When students were able to see industry actors and graduate students that looked like them in positions related to the building industry such as civil engineers or tradespeople, they were more accepting of these careers as possibilities for themselves in their own futures. We were able to observe and document a shift in case study students' perceptions of their own social mobility or inclusion in these spaces, which our data hints is due to this novel feminized space.

Alongside this increased female participation, the authors observed an affinity for social justice and environmental-themed projects. By analyzing our case study students presentations and juxtaposing them with our general VDC group presentations, we were able to document more incidences of social awareness and environmental concerns factoring into students' projects. Our case study students were focused much more on the social implications of their projects than solely on the built environment. Despite having an increased focus on social justice, the case study students excelled in both the virtual and physical modeling of the built environment. The authors documented that our case study students produced better products which were also more meaningful to society at large. These projects were also more sensitive to worker safety.

Limitations and Recommendations

We introduced specific situations into the experiment platform to explore issues relating to feminism and social justice. However, these situations are not normally seen in the industry nor at top universities. We assume this feminization of the construction industry is representative of a future gender-neutral construction industry. It is difficult to generalize our findings because of the limitations of a small sample size and the unique setting in San José, California. We recommend that educators adopt the feminized gender-inclusive VDC curriculum guided by PBL. An increase in young women entering the energy sector trades would likely bring social change to the worksite.

In particular, our interviews with tradespeople brought out questions relating to childcare public policies and provisions in agreements through social public policy such as those being developed by David Campos' County offices of equity and social justice (Bay Area Reporter, 2018). Union training centers are an important college pathway that develops both the next generation of a skilled workforce as well as the next generation of union leadership; we see an expanded role of the union education system in the oversight of workforce education pathways. The authors recommend continued research into the role of a feminist positive pathway in a cultural change towards a greater focus on safety, environment, and society.

In creating our pathway to building trades careers, we believe we are curating more efficient educational experiences for all young women—even those who do not become part of the building trades. Through observations with students like Emily, we now know our reach extends beyond a simple pathway into the overall perception of the building trades as facilitating young women's social mobility. This means that although Emily may not be applying to work in the trades directly, her perceptions of them are forever changed, which as a result will make her a more effective engineer and advocate for the trades. We also consider that none of our case study students entered the building trades apprenticeships directly out of high school. This complicates what we consider to be a successful STEM-CTE pathway. Further metrics are needed to measure the success of these pathways. We recommend that social mobility be added as a feature of a successful STEM-CTE pathway.

There are barriers in the education system that are outside our reach, such as prerequisite courses. Before applying to an apprenticeship as an electrical worker, students are required to have begun a STEM education pathway as a prerequisite (IBEW-NECA, 2020). It is possible that secondary schools do not perceive CTE students as needing STEM prerequisites.

From a policy standpoint, there is a need for workforce education to provide services such as childcare, emergency cash assistance, mental health services, and domestic violence services (Anderson et al., 2017).

This paper suggests that the importance of including women in the construction industry is not for the benefit of women only or because it is in and of itself a worthwhile goal, but because men, too, stand to benefit from them being there: we see this in topics of social justice, safety, and environmental protection. We agree that this cheapens the effort we are making, especially because we do not discuss in detail the benefit to women themselves.

CONCLUSION

Research Summaries

In the first study of this dissertation, I have taken steps toward better understanding the metrics that explain functioning AS-CTE pathways. In contributing to Project-Based Learning (PBL) theory, Arantes Do Amaral et al. (2018) found that seven PBL essentials form good learning outcomes; Creghan and Adair-Creghan (2015) showed that a measurable outcome of PBL is higher attendance, after which Plasman and colleagues (2021), using a case of AS-CTE, framed attendance as a predictor of efficacy. Through an ethnography in a community college, I observed that when social mobility was added as a metric of high-quality PBL with AS-CTE in a predictive framework of education success, attendance levels improved. This study concluded that using the seven essentials and social mobility as a metric of PBL helps better to explain the observation of PBL's improved efficacy.

The second study in this dissertation investigated an opportunity gap (Ladson-Billings, 2013) which contributes to students' perceptions that AS-CTE does not lead to advanced STEM degrees. That perception forms a resistance to AS-CTE pathways, hindering efforts to include underrepresented demographics such as those who identify as women. As a result, these pathways are male-dominated. My study explained to what degree this opportunity gap influences perceptions of obscure high-wage, high-skill careers by youth underrepresented in careers in the built environment, such as civil and environmental engineering. The opportunity gap was disrupted when students participated in a Virtual Design and Construction (VDC) PBL curriculum. This study followed a pilot humanities-themed VDC-PBL curriculum. Using a community-based participatory research (CBPR) method, through an ethnographic role, observations were checked against a student perception survey. This study revealed that

disrupting the opportunity gap (1) narrows a 'perception' gap, (2) teaches virtual design and construction style collaboration, and (3) allows youth to explore topics in sustainability and environmental justice.

The final study of this dissertation investigated how STEM-CTE pathways present barriers to inclusion through hegemonic masculinity (Connell & Messerschmidt, 2005). I employ a feminization of a PBL mentor intervention to help break down the barriers of hegemonic masculinity in secondary STEM-CTE classrooms. Through ethnographic action research (Hartmann et al., 2009), I found evidence that the humanizing of our VDC-PBL intervention allowed for sites of resistance to gender norms. This study calls for the abandonment of male-dominated curricula and their replacement with learner-centered interventions informed by Connell and Messerschmidt's (2002) hegemonic masculinity theory.

Research Implications

The research presented in the three studies of this dissertation explore the potential benefit in formalizing the implementation of social mobility as a measurable metric. This formalization has contributed to opportunity gap theory with an improved understanding of the role that education has in shaping perceptions of opportunity and social mobility through a disruption and narrowing of the opportunity gap, and it also contributes to Workforce Virtual Design and Construction theory with another explanation of how the workforce and VDC interact. Specifically, this research looks at the perceptions underrepresented youth have about the building industry as a potential career and pathway for higher education to achieve social mobility. This dissertation also identifies the existence of barriers for young women entering high-skill, high-wage jobs in the construction industry. Recognizing and documenting young women's low participation in the STEM-CTE courses that feed the labor force is crucial for

remediation. Uncovering the gendered messages young women receive and the resulting barriers which function to exclude them from perceiving social mobility will help to address blatant and latent hegemonic masculinity. This dissertation takes the first steps to recognize these barriers and works to address the toxic masculinity and lack of female inclusion in this industry. The recognition of the existence of these barriers is crucial to dismantling them and advocating for more equitable access to this industry and its occupations.

This line of research works to move the field toward a more equitable future for those in the workforce and education system. By problematizing the historical roots of workforce pathways we need to remain cautious to avoid superficial amelioration of past harms caused by these pathways. This research puts in the hard work to take the palimpsest of the workforce education recipe and scrape away the prescribed instructions, analyzing each layer to avoid rewriting historical injustices. This recipe must be critically examined in order to be more justly rewritten.

This dissertation lends insight into the ways that postsecondary Career Technical Education institutions struggle to fulfill their mission to increase employment and social mobility for students from marginalized communities. Historically, access to education is not enough. Groeger (2017a) reminds us that "increased access to education, so often hailed as a road to opportunity, gave rise to a new form of social inequality in the modern United States" (p. 2). Groeger's (2021) critique highlights 'credentialism' where unequal access to education credentials perpetuates an elite ruling class.

Knowing to what degree each postsecondary institution generates social mobility allows for recommendations toward best practices. This research is motivated by service to my community and my aim to inform community stakeholders which institutions are functioning to

facilitate workforce mobility. Too often, underrepresented minorities and/or low-income individuals carry the burden of social and environmental injustice that impacts their livelihood and lack of mobility. In the high-tech region, neighbors are exposed to environmental stresses and contaminants that measurably impact community health (Montoya et al., 2018). Furthermore, many live with neurotoxins like lead paint, carcinogens like asbestos, or in close proximity to brownfields and manufacturing facilities of unknown and mixed pollutants (Montoya et al., 2018).

Future Research

Silicon Valley has impacted communities—composed mainly of minoritized individuals—that are nine times more likely to reside near toxic facilities and sites (Massey, 2004). Efficacious postsecondary STEM pathways help to ameliorate these environmental and structural inequities by providing true pathways to job skills that will result in higher wages. Uncovering and creating these functioning pathways helps to increase a homegrown skilled workforce. Job skills and prosperity allow community members to improve the environmental impacts of buildings around them and to join a growing and prosperous workforce (Fischer, 2006; Peterson et al., 2011). My research agenda has the potential to help bridge gaps to postsecondary STEM for communities with historically underrepresented populations that have struggled to enter the college–career pipeline and careers in the built environment. Finally, this line of research and action would work to reduce hegemonic masculinity likely bringing social change to the worksite. My future research agenda as a visiting scholar and faculty member will incorporate three intersecting themes which often overlap.

Following with this line of research I will work with researchers from both Stanford University's Center for Integrated Facility Engineering and Santa Clara University's School of

Education, to continue STEM pathway and course iteration in post-secondary civil engineering and built environment courses in Silicon Valley, CA. I will take a mentorship and latter author role on the forthcoming research project, which includes ethnography and case study interviews of a Problem Based Building Information Modeling course.

To address opportunity gaps in STEM curricula, including engineering education, I am continuing to research and document these gaps through our Research-Practice Partnership with practitioners in Silicon Valley, and in collaboration with CSUSB, where we are iterating civil engineering pathways and curricula and researching their efficacy. Through the same RPP, I continue to iterate STEM-CTE pathways at the secondary level. I use hegemonic masculinity theory as a lens to understand these barriers more acutely. I continue to refine interventions for curricular efficacy.

The three themes of my research agenda make important and timely contributions to the field of STEM and engineering education more broadly. Uncovering and working to remediate an ineffective metric of program efficacy allows others to push their metrics of success and build on this line of research. Revealing an opportunity gap which impacts marginalized youth more acutely, contributes to actively designing pathways and curricula to disrupt this opportunity gap. Finally, interrogating toxic masculinity within STEM pathways, is novel and uncovering the impacts of those with compounding marginalizations and working to dismantle those toxicities is of the utmost importance.

APPENDIX

The following questions and categories were shuffled into a double-sided 5-point Likert scale survey with a range from totally true to totally untrue. The employed survey was modified from a validated 7'C's survey (Ferguson, 2012).

Survey questions by category

Building energy efficiency

I know what it takes to make a building operable.
I know what is necessary to make a project sustainable.
I have used computers to help design a project to be more efficient.
I have worked with sustainable energy related to construction.

Sustainability

I consider sustainability when I design a project.
Planning for water use is important in designing a building.
Where materials are made can affect if a project is buildable.
I have worked on a project where sustainability was important.

Knowledge of career options/ possible careers for them

I have been exposed to possible careers in my classes.
I have visited a place where I could see myself working at.
I have met people who work in a career I am interested in.
I know what job I want in the future.
I have gained skills for a job in the future.

Positive environmental education

I learn better when I am outside.
I like to see and interact with what I am learning.
I learn better through outdoor projects than through lectures and notes.
I prefer to see and interact with what I am learning.

Teacher Support

My teachers are respectful toward me.
If I walked into class upset, my teacher would be concerned.

If I came back in three years, my teacher would be happy to see me.
When my teacher asks how I am doing, they really care.
My teacher cares about me.

Confidence

If I run into a problem with a project, I can fix it.
I am capable of getting an A in this class.
I am capable of working hard and achieving my goals.
I am capable of learning the skills to succeed in the future.
I am confident in my ability to succeed in this class.

Social Justice/ Community

What I learn can help me to help my community.
I care about the people in my community.
I feel like I am part of my community.
I care about people who are suffering in my city.
My actions impact other people at my school.

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