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Table of Contents

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Envisioning Career Technical Education as a Platform for Student Empowerment

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Introduction

Career Technical Education (CTE) has emerged as a promising platform to improve educational preparation for students underrepresented in the sciences. Despite its potential, funding inequalities, lack of teacher preparation, and inadequate industry connections affect the quality of CTE programs. This paper describes Teachers and Students for Community Oriented Research and Education (TSCORE)[1], a community-university partnership that focuses on CTE health science teachers and provides pedagogical tools, knowledge, and connections needed to bring local, cutting-edge health disparities research into classrooms. Framed in critical pedagogy, TSCORE delivers 1) teacher empowerment, 2) implementation support, and 3) student conscientization. Teachers receive 85 hours of professional development on health disparities, project based learning, and curriculum development. Pedagogical support is provided during the year as teachers use newly created curricular units to guide students in inquiry that problematizes the state of health in their communities and engages them in developing community-based interventions to improve health outcomes for their people. TSCORE challenges the academic-vocational divide by moving past views of CTE as a job training platform for entry level positions and invites students to experience first-hand how a career in science and research can have a positive impact on the health of their communities.

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Literature Review

Career Technical Education (CTE) has emerged in the last decade as an evidence-based approach to boost graduation rates and to provide students with opportunities to gain exposure to a vast array of careers (Levesque et al., 2008). Studies of CTE participation have found that students who take at least three CTE courses participate in more rigorous coursework (Aliaga, Kotamraju, & Stone, 2012), take more math and science courses at higher levels (Stone & Aliaga, 2003), are more likely to aspire to and earn bachelor's degrees (Levesque et al., 2008), and are less likely to drop out of high school (Gray, 2004). Despite variability, most CTE programs are characterized by a sequence of courses that blends standards-based academics with hands-on, challenging career-preparation skills. Those funded with federal Perkins IV grants are required to demonstrate academic rigor, seamless postsecondary connections, and college preparation in career-focused education.

Despite CTE's potential as an empowerment platform, questions remain regarding its effects on urban districts given the historical, and potentially outdated, connections between CTE and ability tracking. In fact, a growing body of literature is raising concerns that although CTE students might experience higher employment rates directly after graduation, participants seem to suffer when looking at long term outcomes as more jobs require postsecondary credentials and broader competencies beyond technical skills (RWIN, 2017). CTE curricula can no longer solely focus on skills demanded by labor markets that are likely to evolve and change over time. Rather, the 21st century demands that students be equipped with critical thinking skills, the ability to look for and synthetize information, and the capacity to develop solutions to novel problems. These transferable skills allow students to be competitive in contemporary labor markets and continue career advancement in the real world.

CTE programs now serve the vast majority of public high school students, as approximately 92 percent of high school students have taken at least one CTE course (Levesque et al., 2008). In the state we work in, Kansas, enrollment in CTE classes has increased dramatically over the last three years. In the 2015-2016 school year, 71,109 Kansas students were enrolled in secondary CTE courses, an increase of 131 percent in the past year (PCRN, 2016). Approximately 1,400 students earned industry-recognized credentials, including 1,022 in a health-related field. Although the CTE course enrollment has been increasing, CTE pathway concentration and completion rates have been lagging. For instance, in one of the major urban school districts in Kansas, only 10% of health science students who took entry-level courses were pathway "completers" which is half the national average of a 20.8% pathway completion rate (Levesque et al., 2008).

State and district CTE leaders recognize that student failure to complete CTE pathways might stem from a multiplicity of factors affecting urban districts including 1) fear of challenging higher level technical and application course content, 2) a lack of understanding of how the higher level courses will prepare students for health careers, and 3) a lack of preparation of health science teachers to teach higher level courses

(Aliaga et al., 2014; Castellano et al., 2012, 2017). Moreover, there seems to be consensus that while affluent suburban districts have thrived in establishing industry connections and aligning their efforts with curricular standards, well-intentioned urban schools continue to struggle to deliver quality CTE programming to their students. Finding industry mentors in urban neighborhoods struggling with poverty and staffing high level CTE courses with qualified teachers are some of the barriers faced by urban schools, including the very schools involved in the program presented here (Brand, 2008; Bridwell-Mitchell, 2017).

The goal of this paper is to describe the Teachers and Students for Community Oriented Research and Education (TSCORE) program. TSCORE joins a growing number of programs highlighting the potential of CTE as a platform for innovation, student engagement, and curriculum integration. We agree with Jocson that "CTE can be a place where what it means to be human and educated is not simply tied to shifting labor markets" (Jocson, 2018, p.642). TSCORE engages students in a process of critical awareness that leads them to analyze the current state of health in their communities and to develop action plans for change. We offer teachers learning experiences tailored for those teaching in the urban core and organized around the themes of health disparities, public health, and social determinants of health. By posing problems within the context of students' realities, TSCORE teachers help students envision how science (biomedical, clinical, behavioral, and social) and research can serve as powerful tools to ameliorate the diseases and illnesses impacting their communities. Students witness firsthand the workforce contributions they can make by choosing careers in public health research along with other more traditional medical and health science opportunities. This paper describes the TSCORE model.

Theoretical Framework

TSCORE is grounded in critical pedagogy, an educational approach based on the works of Paolo Freire (1970, 1972, 1987). Following Freire, we reject traditional "banking" methods focused on transmission of knowledge and skills dictated by shifting labor markets (Freire, 1970). In such a system, teachers deposit knowledge on students who in turn regurgitate it without deeper understanding. In contrast, Freire proposes that the main aims of education should be to develop critical awareness of students' own social and personal circumstances and to create new knowledge rooted in students' realities and aimed at addressing the injustices and inequalities of an oppressive world. More than simply providing contextualized lessons, for learning to be "authentic" it should lead to conscientization. Freire defines conscientization as "to learn to perceive social, political, and economic contradictions and to take action against the oppressive elements of reality" (Freire, 1970, p.17). Conscientization is therefore a call for action that clearly surpasses the boundaries of the traditional classroom. It also challenges traditional classroom-as-a-container discourses that prescribe where learning "takes place." It calls for the creation of learning networks that confer teachers the opportunity to expand their own knowledge and to cross the "in-school"/"out-of-school" border. Finally, applying a Freirean framework to CTE courses requires challenging traditional approaches to CTE that are centered on workforce readiness and market demands. The reductionist approach found in many current CTE classrooms ignores the ever-changing nature of our global markets and the skills that they demand. Equating CTE to mere production "misrepresents the capacity of individuals to be active participants with the social knowledge, symbolic power, and other forms of capital that can enhance their valued participation within particular social spaces" (Bourdieu, 1986, 1989, cited in Jocson, 2018, p.659).

Using a public health lens, TSCORE pushes CTE teachers and students to problematize the state of health in their communities and to start conceptualizing community-based interventions that could improve health outcomes. In this sense, empowering students with the tools to become inquisitive about their surroundings and to enact change, we strive to "transform the outlook of marginalized youth from one of desperate resignation to one of critical awareness and pragmatic optimism" (Noguera, 2007, p.18). It is this sense of hope that can have a positive impact on students' self-efficacy, knowledge, and interest in STEM careers.

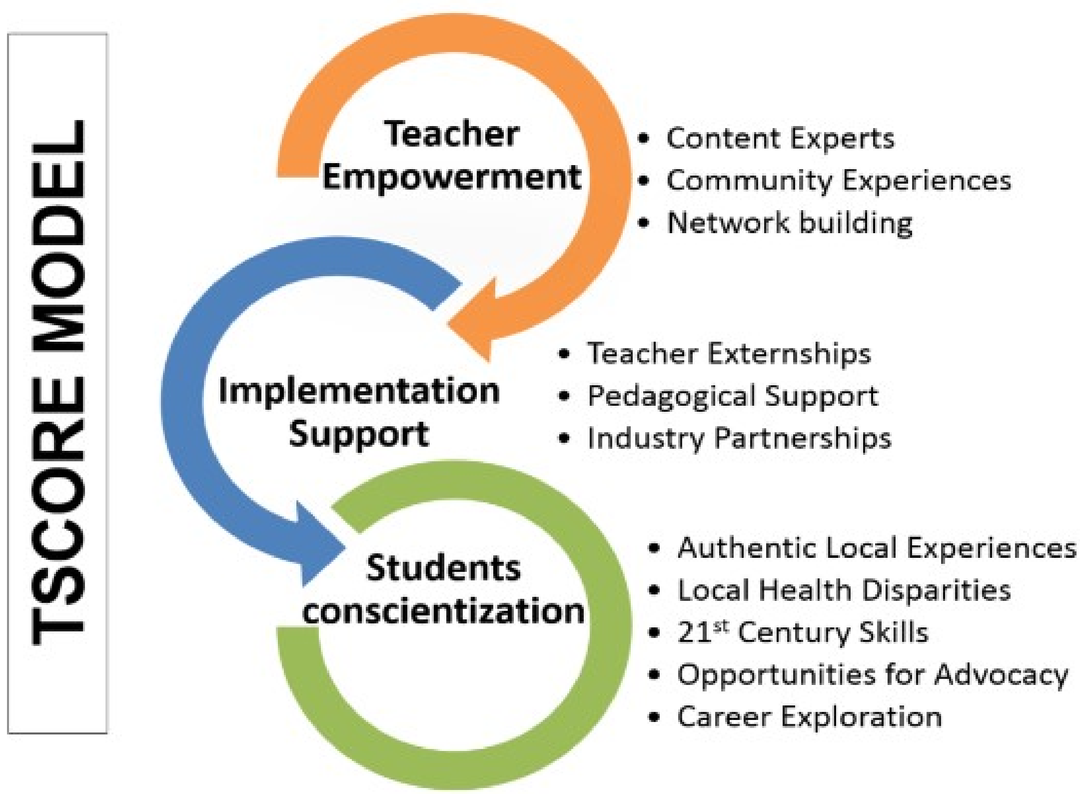
We approach curriculum development and teaching from a dialogical perspective with the goal of co-producing knowledge in collaboration with teachers and students; the type of knowledge that is reflective of the perspectives and experiences of local populations. The TSCORE curriculum is rooted in students' own community whose inhabitants experience high levels of poverty and unemployment, low access to health care services, and linguistic and cultural barriers that limit their ability to thrive. Hence, we challenge teachers to abandon the traditional hierarchy that confers teachers' authority over students and the boundaries delineating teacher-student interactions. A teacher working within a critical pedagogy framework acknowledges that "nobody knows everything" and that education is transformative. As a facilitator, the teacher poses real, present, and local problems to students and challenges them to think critically about their own realities and to develop solutions to the problems their own communities face. This pedagogy of questioning invites students to discover reality in the root causes of health inequities, to think critically about the conditions in which they live, and to feel empowered to change them.

Although the literature on Freire's work is extensive, his work does not escape criticism. The applicability of his theories to contexts outside Brazil as well as the complexity of his epistemological foundation and lack of clear and practical pedagogical models for the classroom are some of the most salient (Au, 2007; Beckett, 2013; Jackson, 2007). To address these shortcomings and given the focus of TSCORE on praxis, our project adopts project based learning (PBL) as its method of delivery due to its focus on engaging students by empowering them to investigate authentic, complex questions or problems, build collaboration and project management skills, and respond to meaningful, relevant challenges (Mergendoller, 2018). Pragmatically, PBL relies on "rigorous projects [that] are carefully planned, managed, and assessed to help students learn key academic content, practice 21st Century Skills (such as collaboration, communication and critical thinking), and create high-quality, authentic products and presentations" (BIE, 2012). PBL places a great deal of emphasis on student-centered, inquiry-driven practices, principles that are highly aligned with Freire's pedagogical philosophy.

The TSCORE Model: Praxis and Implementation

To ensure successful development and implementation of the TSCORE program, we convened a diverse team. The team includes individuals with experience in public health, health disparities research, and community-university partnerships as well as experience teaching, developing curriculum, and designing and evaluating professional development opportunities for teachers in the urban core. From 2016-2018 and over the course of three school years, we have worked with a total of 21 teachers in two major urban districts in Kansas. As shown in Figure 1, the TSCORE model is organized around three intertwined priorities: 1) teacher empowerment, 2) implementation support, and 3) student conscientization. Each of these areas are described below in Figure 1 and subsequently in the text that follows.

Figure 1. Teachers and Students for Community Oriented Research and Education Model



<u>Teacher Empowerment</u>
Each summer we host high school teachers on campus for an 85-hour professional development opportunity, the TSCORE Summer Institute. Although we originally planned on limiting recruitment to CTE health science teachers, given districts' movement towards career-focused academies, we expanded our guidelines to include core content teachers within the health science academies. Cross-curricular opportunities have proven extremely effective in raising the bar and maximizing our impact within the schools.

The TSCORE Summer Institute is organized around three main themes: health disparities, PBL, and curriculum development. We know that teachers' content knowledge highly influences their professional practices and student achievement. Teachers with advanced science knowledge pose questions, pursue unanticipated inquiries, and engage students in co-construction of knowledge, while teachers with limited knowledge most often revert to direct instruction and focus on factual knowledge (Davis & Petish, 2005; Hauslein et al., 1992). Moreover, following a national trend, our teachers often reside in counties other than the one where they teach; even when they do, they tend to be unaware of the disparities their community members face (Downs, 2016). Using a public health lens, our Summer Institute provides teachers with the knowledge and research connections they need to develop a curricular unit that is contextualized in students' realities and empowers students as agents of change within their communities.

To mirror the inquiry process, the TSCORE Summer Institute begins with a tour of the community that highlights both health disparities and local resources. The experience is designed to spark teachers' interest in the communities surrounding the school and to start problematizing the realities in which their students live. Teacher fellows meet with community partners, expand their social network, and start to define their project ideas and driving questions for their units based on the reports provided by community sites that work with the same students and families our teachers serve. Examples of sites include the local health department, the Community Health Council, and non-profit organizations that work with vulnerable populations.

The four-part TSCORE Summer Institute is organized as follows:

Part One focuses on providing a working definition of health disparities. Using a pedagogy of questioning, TSCORE staff leads teachers to think critically about factors affecting health and how much control people have over their health. Focusing on real data and the Robert Wood Johnson Foundation County Health Rankings Model for health outcomes (UWPHI, 2018), the group problematizes how social determinants of health (i.e. health behaviors, clinical care, social and economic factors, and the built environment) affect health outcomes. Context specific examples such as health insurance access, infant mortality, unemployment rates, imprisonment, and life expectancy are discussed and compared to adjacent affluent counties.

Part Two dives deeply into what community researchers actually do. Using real, local case studies, university health disparities researchers share with teaching fellows the process they follow to come up with research ideas. From reading journal articles, community magazines, local health reports, to conversations with researchers, fellows are introduced to ideas for potential unit topics. Emphasis is placed on researchers' approach to establishing milestones for their projects. Parallels are constantly drawn between the process of research, evaluation, and assessment and the unit planning process. The approach is dialogical, and both researchers and fellows contribute with questions and comments to find connections. Reflecting on the community tour in part one, teachers start to narrow down their topics and draft assessments for the unit they are developing by mirroring the evaluation process described by researchers.

Part Three provides teachers with the opportunity to explore "alternative" methods of data collection, particularly ethnography, photovoice, and interviews. These methods are not only great tools for differentiation in the classroom, but they also provide teachers with the opportunity to offer students a different perspective on what research can look like. A multifaceted team of researchers offer examples of how these alternative methods are used in research to capture the voice of the underserved and to provide the other side of the picture that community statistics rarely deliver. Community activists, faculty, and health professionals continue facilitating professional development sessions by providing local cases of how data have been utilized to improve the surrounding communities such as bringing grocery stores to local food deserts, building exercise trails, or opening Affordable Care Act enrollment centers. Teachers also learn about several advocacy models including the World Health Organization practical guide to successful advocacy, a simple seven-step plan for effective advocacy which includes identifying target audiences, developing key messages, and selecting implementation strategies (WHO, 2008).

Part Four enables educators to expand their social network and to apply newly acquired work-based knowledge to their curriculum development. As teachers plan their units, they are scheduled to meet with members of their newly acquired professional network, at which point they begin generating commitments for guest speakers, field trips, or potential research mentorships for themselves and students. Individual sessions for each teaching fellow are scheduled with both content and pedagogical experts to provide feedback, share ideas, and ensure "authenticity" of the curriculum.

Unit examples developed by TSCORE teaching fellows and staff are shown in Figure 2, below.

Figure 2. Teacher and Staff Developed Units

Unit Title; Driving Question	**Learning Objectives**
Clean Air Project: *How does asthma affect the*	• Research the impact of air quality on students and the learning environment.

teenage body?	• Develop and conduct and air quality assessment of school. • Write a letter to school leadership with recommendations for action.
We Are the Change: *How can we improve socio-economic and health outcomes in our community?*	• Conduct a community needs assessment based on the social determinants of health. • Lead focus groups to elicit expert and community feedback. • Implement an intervention (i.e. health fair, job fair) to address needs.
Chance the Researcher: *How can we help the community overcome the probability of poor health outcomes?*	• Collect, analyze, and display relevant data to support interventions. • Develop an intervention that educates the community and/or seeks to prevent chronic diseases.
Leading the Way to Better Water: *Is our water safe to drink?*	• Research the impact of drinking water quality on communities. • Analyze data of lead levels and other contaminants in drinking water. • Create public service announcements in languages of the community to address issues in water quality and health disparities.
Nurturance & Resilience: *What do students need to thrive?*	• Conduct ethnographic research to understand resilience in different cultures. • Collect and analyze survey data to study the school climate's effect on student resilience. • Provide recommendations to school leadership to promote a climate in which students can thrive.
Infant Mortality: *How does one's lifestyle and community affect the health of an unborn child?*	• Recognize geographic health disparities in infant mortality. • Create an informative campaign targeted to decrease disparities in infant mortality in the local community.
Mental Health Disparities: *How do social determinants of health and physical health affect mental health?*	• Research the upstream causes of local mental health disparities. • Conduct a school-based mental health assessment. • Plan, organize, and implement a community health event addressing identified mental health needs.
***Health Disparities:** *What factors contribute to the health outcomes in my community?*	• Analyze health disparities related to socio-economic status, gender, geography, culture, and access to health care. • Describe the social and environmental factors that contribute to different health outcomes in different communities.
***Health Advocacy:** *How can I advocate for the health of my community?*	• Examine the root causes of health outcomes by exploring three public health issues: food deserts, violence, and tobacco. • Practice authentic data gathering and analysis skills applicable to community health advocacy. • Choose a public health issue; apply advocacy principles to create an advocacy project that impacts their community.

**Staff developed units. Download at:* www.tscoreks.org

Implementation Support

Roughly 50 percent of all urban public school teachers nationwide leave their positions in less than three years because they do not feel prepared (Ingersoll, Merrill, & Stuckey, 2014). CTE teachers struggle with access to meaningful professional opportunities due to budget cuts and a hyper-focus on "core" subjects (Deeds, 2017). Research around the effects of coaching on teacher practices is well documented with solid evidence indicating that those receiving post-intervention coaching consistently outperform those who only receive coursework (Neuman & Wright, 2010; Walpole, McKenna, Uribe-Zarain, & Lamitina, 2010; Sailors et al., 2014).

By the end of the Summer Institute, participating teachers have a well-developed unit as well as the professional network needed to bring outside partners to their classrooms. Our support, however, does not end there. The TSCORE model includes a year-long implementation support program that includes on-site coaching, externships, and industry connections. Each teacher receives at least three one-hour observations and three additional fifteen minute "pop-ins." During the classroom visits, program staff, in partnership with instructional coaches at the local schools, rely on different tools to support fellows, including cycles of reflection activities where teachers identify challenges, discuss causes of learning gaps, and develop an intervention plan. Through email and online tools, teachers interact with health disparities researchers and the TSCORE staff to share resources, ideas, and solve challenges. TSCORE teaching fellows receive feedback from their peers, research team, and community advisory board.

Additional professional development sessions are based on participants' needs and interests. For instance, one-day externships bridge classroom learning with real world challenges by providing teachers with opportunities to present their unit to experts in the field, obtain feedback to increase rigor, deepen their understanding of a specific topic, and develop relevant soft skills associated with their unit's content. Figure 3 includes two examples of externships.

Figure 3. Externship Examples

Example 1. "We Are the Change" = Sociology/Economics Teacher
• Community organizations with job fair expertise highlighted event logistics, provided marketing tools, and gave insight into anticipating stakeholder and participant needs. • Public health outreach experts demonstrated how to develop quantifiable goals, evaluate interventions, and conduct focus groups.
Example 2. "Chance the Researcher" = Health Science and Math Teachers
• Biostatisticians explored methods of data collection, shared classroom-ready examples of current biostatistics research, and invited them to a local StatKC conference to build students' professional networks and knowledge of careers that use math in health.

• Public health researchers shared questions that guide the research process, explored the role of bias in survey formation, and provided tools to evaluate community-based research.

Student Conscientization

Urban CTE programs frequently use one-time campus or workplace tours to expose students to industry-related programs and careers. These trips are often disconnected from the course content and students' realities. TSCORE aims to empower students with both its method and the promotion of "localized" knowledge. Using a public health lens, the TSCORE curriculum pushes students to gain awareness about their own community's position within the larger society. Our program focuses on student conscientization, that is, "the process in which men [and women], not as recipients, but as knowing subjects, achieve a deepening awareness both of the socio-cultural reality which shapes their lives and their capacity to transform that reality" (Freire, 1972, p.51). To facilitate this process, the TSCORE model embraces Freire's premise in teaching literacy to oppressed communities: "to read the word is to read the world" (Freire & Macedo, 1987). All authentic education should investigate learners' realities and provide opportunities for students to establish connections between their world and the content being studied.

For instance, as exemplified in Figure 2, students in one TSCORE classroom investigated the question, "*How does asthma affect the teenage body?*" Rather than exploring the respiratory system from a purely anatomical perspective, learners investigated the system within the context of air quality and asthma, a condition that continues to disproportionality affect children in the urban core. In the Kansas City Metropolitan area, 12.6 percent of children 0-17 years old have asthma (CMHKC, 2016). In this unit, students explore potential reasons behind these alarming asthma rates in their community, including potential causes within the school environment. They conducted an observational air quality assessment and developed solutions that were presented to the school leadership. Learning about the effects of social determinants of health on the respiratory system allows students to question traditional discourse that blames personal choices on health outcomes like asthma; it also provides them with an opportunity to affect real change within the school and in their community at large.

At another TSCORE site, a cross-curricular collaboration between a math and a health science teacher focused on: "*How can students help the community overcome the probability of poor health outcomes?*" Students analyzed data on their county's health outcomes and developed interventions based on results. Forty-seven students presented their interventions at a Graduate Student Research Forum, which provided an opportunity for feedback and to gauge experts' reactions to their ideas. Although county databases were often used as "evidence," a plethora of projects employed both qualitative and mixed-method data collection techniques that teachers learned about during our Summer Institute and externships. The skills teachers learned and integrated into their TSCORE unit ultimately contributed to students' ability to connect with the health disparities being explored at a personal level.

Moving Forward with the TSCORE Model

As reflected by the growing number of CTE programs, well-resourced school districts have seen the potential of high-quality CTE programs as a delivery system of 21st century skills and STEM competencies. For urban schools struggling with high drop-outs rates, promising evidence points to CTE's potential to increase graduation and postsecondary education engagement. The TSCORE model relies on CTE's natural focus on contextualized learning that emphasizes connections between the classroom and the real world to foster innovative instructional strategies like project based leaning that embrace the Freirean view of conscientization. Nevertheless, our model is also designed to address some of the challenges that continue to affect CTE programs, particularly in urban districts, such as its view as a path for low-performing students, its quality and the preparedness of its teachers, its alignment with national standards and core-curricular subjects, and the high drop-out rates in some pathways. By empowering teachers with individualized learning experiences, opportunities to bring local, cutting-edge health disparities research into classrooms, and expand their professional network, TSCORE hopes to propel CTE health science courses in urban districts as an "educational pathway of choice" and a potential platform to increase the number of minority students interested in a career in health care.

Envisioning CTE as an empowering platform to prepare students for college and beyond, particularly in under-resourced, underserved districts, will require a community effort and reliable partners committed to urban education and to diversifying the health professions. For those working in academia, it entails paying attention to the reality of schools and molding our efforts to serve teachers' and students' needs, including identifying partnerships that can get students to establish real and tangible connections between research and its potential impact on the quality of life in their communities. For under-resourced urban schools that continue to struggle to forge and maintain the industry networks needed to build rigorous programs, partnerships with academic institutions and community sites like the one proposed in TSCORE assist in equalizing the field for all students. Trained teachers integrating these partnerships into curriculum further provides a sustainable channel to increase the number of underrepresented students in science and research.

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The Future of CTE Teacher Preparation Programs in Florida's Universities

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Introduction

Career and technical education (CTE) teacher preparation programs prepare subject matter experts to teach career-themed courses at the secondary and postsecondary levels. Course objectives and curriculum provide prospective CTE teachers pedagogical knowledge and best teaching practices, which in turn produce quality teachers. Research has revealed a positive relationship between teacher quality and student learning outcomes (Darling-Hammond, 2000). More specifically, Darling-Hammond's (2000) study noted professional teacher education has been identified as a key factor in quality teachers which, in turn, helps to create positive student outcomes across all 50 states. The sustainability of CTE teacher preparation programs is necessary to produce effective teachers.

Problem Statement and Purpose of Study

CTE programs have seen increased student enrollments in the past decade. From 2013/14 to 2015/16 school years, Florida's career and technical education (CTE) student enrollment increased by approximately 20% in Grades 6 through 12 (Florida Department of Education, 2017). With a student enrollment increase in career-themed courses, one would surmise an increase in CTE teacher education programs would occur to support the additional workload. However, CTE teacher preparation Bachelor degree programs have been steadily decreasing since the 1990s (Bruening, Scanlon, & Hodes, 2001; Fletcher, Gordon, Asunda, & Zirkle, 2015; Lynch, 1990). Lynch's (1990) study identified twenty-seven (27) CTE teacher preparation programs in Florida. Fletcher et al (2015) identified seven available programs. In 2017, four CTE teacher preparation programs remained (Martino, 2017). As of Fall 2018, one CTE teacher preparation Bachelor degree program is no longer offered, leaving three active CTE teacher preparation Bachelor degree programs in Florida's state universities. Various questions arise from the incongruous supply and demand of Florida's CTE teachers. Are the current CTE teachers knowledgeable in pedagogy and best practices? Who will train the new CTE teachers? What are the reasons for the decline in available CTE teacher preparation programs? How do we keep the current programs active?

To better understand this phenomenon, this article discusses Martino's (2017) qualitative, Grounded Theory dissertation study that explored experiences and perceived program conditions for sustainability. Participants included past and present CTE teacher preparation program educators and administrators in Florida. Data collection included semi-structured interviews, peer debriefing, memo-taking, and journal notes. The study was guided by the following research questions (a) How do past and present undergraduate CTE teacher preparation educators and administrators describe their program experience and program sustainability?; and (b) What perceived conditions do past and present undergraduate CTE teacher preparation educators and administrators believe are essential for program sustainability? (Martino, 2017). Analysis was conducted using a constant comparison approach until saturation occurred. The CTE Teacher Preparation Program Sustainability Framework was developed as a result of the findings. Based on the results of the study, some implications for best practice are presented.

Literature Review

To provide a better understanding of the declining Florida CTE teacher preparation program issue, review of the existing literature on CTE teacher certification, degreed CTE coverages, CTE teacher preparation program research, and studies on sustainability frameworks are presented.

Professional Educator's Certificate

The Florida Department of Education (FLDOE) oversees the approval for degreed teaching certificates in all 67 public school districts. A CTE teacher applicant must apply through the FLDOE website. The application requirements include a fee, official college transcripts, and other documentation as indicated. The official college transcript must show a completed Bachelor's degree from an accredited college or university as well as subject matter courses and four mandatory professional education courses: (a) teaching methods; (b) course construction; (c) lesson planning and evaluation; (d) teaching special needs students (Florida Department of Education, 2017). Once the CTE teacher applicant is approved, a temporary three-year license is provided with instructions on further requirements to obtain the professional teaching certificate to include a passing grade for three Florida Teacher Certification Examinations (FTCE): (a) General Knowledge; (b) Professional Education; (c) a specific subject area test (Pearson Education, Inc., 2017).

Degreed Career and Technical Coverages

To be eligible to become a CTE teacher, applicants must have 30 semester hours of college level courses in a subject area that align with one of the five degreed career and technical coverages for the CTE teacher professional certificate: (a) Agriculture; (b) Business Education; (c) Engineering & Technology Education; (d) Family & Consumer Science; and (d) Marketing. These degreed coverages are divided into subtopics. It is possible to have an agriculture degreed career and technical coverage professional teaching certificate and teach many subtopic courses within that coverage. Table 1 shows the five degreed coverages and each of the subtopics within the covered areas.

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Table 1
Florida's Degreed Career and Technical Coverages and Subtopic Areas

No.	Agriculture	Business Education	Engineering & Technology Education	Family & Consumer Sciences	Marketing
1	Soil Science	Accounting	Materials & Manufacturing Processes Technology	Clothing Construction	Marketing Theory & Practices
2	Agricultural Mechanics	Economics or Finance	Drafting & Design Technology	Textiles	Economics
3	Food & Resource Economics	Computer Science	Energy & Power Technology	Food Preparation	Finance
4	Animal Science	Business Communication	Graphics Communication Technology	Nutrition	Accounting
5	Agronomy	Business law	Electronics Technology	Child Development	Personal Management
6	Horticulture		Construction Technology	Family Relations	
7	Entomology		Transportation Technology	Housing & Home Furnishings	
8	Forestry & Natural Resources		Biomedical Technology	Home Management	
9			Information Technology	Family Economics	
10			Industrial Systems Technology	Consumer Education	

Note. This information is derived from the Florida Department of Education Teacher Certification website (2017): http://www.fldoe.org/teaching/certification/certificate-subjects/. Table 3 (Martino, 2017).

CTE Teacher Preparation Program Research

To date, nine national and local studies regarding CTE teacher preparation program status and standing have been identified (Asunda, 2011; Bruening, Scanlon, & Hodes, 2001;

Clark, 2004; Fletcher, Gordon, Asunda, & Zirkle, 2015; Litowitz, 2013; Lynch, 1990; Martino, 2017; Pucel & Flister, 1997; and Volk, 1993). These studies explored CTE teacher preparation program curriculum, student enrollment, and organizational structure. It is noted that all the studies report a decline in program availability. Some findings indicated low enrollment and alternative certification as reasons for the decline in program offerings.

Sustainability Program Frameworks

Given the consistent decline in available CTE teacher preparation programs, research into the sustainability of the remaining programs is warranted. There are three studies in program sustainability that guided the objectives of this study: (a) Mancini and Marek, 2004; (b) Scheirer, 2005; and (d) Szuminski, 2003. These sustainability studies do not focus on CTE teacher preparation programs; however, recommendations to apply the sustainability framework to other disciplines are stated.

After careful review of the sustainability studies, there appeared to be a similarity in the frameworks. First, all three studies reported internal and external domains for sustainability. The internal domain includes categories that can be controlled by the program stakeholders. External domain categories are controlled by outside stakeholders. The categories from each of the sustainability studies also align in meaning. For clarity and conciseness, new categories were intuitively developed to define and further align the meanings. Table 2 shows the alignment between the new internal and external categories used in this study, the preliminary conceptual sustainability domains, and the three sustainability studies. The preliminary conceptual sustainability domains and categories form the conceptual framework for this study.

Table 2
Comparison of Sustainability Domains

Preliminary Conceptual Sustainability Domains	Existing Sustainability Framework Studies: Mancini & Marek's (2004) Elements of Sustainability	Scheirer's (2005) Program Sustainability Factor List	Szuminski's (2003) Components for Development Model
Internal Support			
Administrative Advocate	Leadership Competence	A "champion" is present	Administrative commitment
Organizational Alignment	Effective Collaboration/Strategic Funding	A program "fits" with its organization's mission and procedures	Job-embedded teacher development activities
Positive Culture	Staff Involvement and Integration	Benefits to staff members and/or clients are readily perceived	Continuous support with both emotional and instructional structures
External Support			
Extrinsic Influences	Understanding the Community	Stakeholders in other organizations provide support	Partnerships to leverage resources
Program Flexibility	Demonstrating Program Results/Program Responsivity	A program can be modified over time	Flexibility in design and implementation

Note. Mancini & Marek's (2004) study has seven domains. Two domains (strategic funding and program responsivity) fit in the organizational alignment and program flexibility domains respectively. Table 5 (Martino, 2017).

Research Procedures

The purpose of this study sought to discover the experiences and perceived conditions essential for program sustainability from past and present CTE teacher preparation program faculty and administrators. Two research questions guided this study: (a) How do past and present undergraduate CTE teacher preparation educators and administrators describe their program experience and program sustainability?; and (b) What perceived conditions do past and present undergraduate CTE teacher preparation educators and administrators believe are essential for program sustainability? (Martino, 2017).

Research Design

A qualitative Grounded Theory design with a constant comparative approach was used. This led to the discovery of patterns in the data using a repetitive process until saturation occurred. It is a recommended choice when the participant sample is small (Braun & Clarke, 2012; Charmaz, 2006; Glaser & Strauss, 1967; Mertens, 2015). The approach allowed for the exploration of past and present CTE teacher preparation educators' and administrators' experiences at a much deeper level. The data was analyzed multiple times while comparing the participants' meaning until themes were apparent.

Participants and Settings

Due to the limited number of available CTE teacher preparation programs in Florida, a purposeful sampling method was used to identify past and present CTE teacher preparation educators and administrators. This sampling method is frequently used in Grounded Theory qualitative studies (Gail, Gall, & Borg, 2007; Mertens, 2015). The method identified five universities: (a) Bethune-Cookman University; (b) Florida Agricultural and Mechanical University; (c) University of Central Florida; (d) University of Florida; and (e) University of West Florida.

Using each university's CTE teacher preparation program department website, potential participants' contact information was collected. Criteria for the selection process included: (a) all participants are employed, or recently retired, in one of the five Florida universities within an active or recently phased-out CTE teacher preparation program; and (b) all participants have or had direct involvement and knowledge of the active or recently phased-out CTE teacher preparation programs' daily operations and/or curricula from one of the five Florida universities.

Twenty-three potential participants were initially identified. One participant shared the study details with a qualified colleague. The participant's colleague asked to be included in the participant recruitment email. Of the twenty-four individuals recruited for this qualitative study, ten participants from four of the five universities responded (n=10), which yielded a 42% participation rate. Nine of the ten participants varied in job duties, CTE experience, and educational degree attainment. One participant recently retired. There were two females and eight males. All participants were given fictitious names to protect their identities. Table 3 lists the participants with a fictitious name, job title, degree attainment, and length of CTE work experience in years.

Table 3
Participant Selection Demographic Data with Fictitious Names

Fictitious Name	Job Title	Degree Attainment	Length of CTE Work Experience in Years
D. Parker	Dean of College	Doctorate	3
D. Miller	Associate Professor	Doctorate	8
D. Harris	Professor	Doctorate	13
D. Martin	Adjunct Instructor	Doctorate	11
D. Clark	Retired Professor	Doctorate	43
D. Lewis	Program Coordinator	Doctorate	14
D. Young	Adjunct Instructor	Doctorate	8
M. King	Adjunct Instructor	Masters	1.5
D. Smith	Program Chair	Doctorate	16
D. Jones	Program Coordinator	Doctorate	7

Note. The participants' first initial is designated with an 'M' which represents a master's degree, or a 'D' which represents a doctorate degree. Table 7 (Martino, 2017).

Measurement Instrument

The participant interviews were guided by semi-structured open-ended questions, which were modified from Mancini and Marek's (2004) quantitative Program Sustainability Index (PSI) instrument. The PSI instrument aligned well with previous literature on program sustainability as well as the Preliminary Sustainability Domains that guided this study. To verify the modified open-ended questions, three higher education teacher education programs educators reviewed the protocol. Suggestions were provided to clarify some of the questions, and revisions were made accordingly. To accompany the protocol, an interview guide was created with probing follow-up questions (Charmaz, 2006).

Data Collection

To ensure the research questions were answered, four data collection types were identified for qualitative research: contextual, perceptual, theoretical, and demographic (Bloomberg and Volpe, 2016). The contextual type contains the participants' culture, setting, and environment. The perceptual type is the perceived interview statements and comments, researcher's journal notes, and advisor's comments on emerging themes. The theoretical type involves the pertinent research studies and review of the literature. Finally, the demographic type includes the participants' job titles, educational attainment, and years of CTE experience.

The four methods used in the data collection process included: interview transcripts, researcher memo-taking, participant member checking, and a peer debriefing. The interviews were conducted either face-to-face or virtually using Skype for Business and were recorded. Then, the recordings were transcribed word-for-word. Journal notes were added to the data as well as notes received by member checking and peer debriefing. All the data was compiled and organized into tables for side-by-side comparison and analysis.

Data Analyses

A two-step (initial and focused) coding strategy was used (Charmaz, 2006). In the first initial stage, the collected data were organized into a series of tables and assigned labels to determine patterns in the information gathered (Bowen, 2005; Gail, Gall, & Borg, 2007; Mertens, 2015). For the initial coding phase, statements of interest were highlighted while transcribing the interviews into a Word document. Once the individual transcriptions were completed, the transcripts (without the researcher's notes) were sent to the respective participants for member checking. Review of the literature, researcher's notes, and archival information was conducted, and notes were added to the tables. The documents were reread, line-by-line, and additional words and phrases were highlighted with comments written in the margin. The data was reviewed a third time, and final notes were added.

The focused coding phase was conducted for each research question. All transcriptions were merged into a Word document along with notes and comments. All participant identifiers were removed. The data was reduced and organized three times into sets of consecutive tables. This process led to the development of themes that emerged from the data. Simultaneously, the Microsoft Office Word 'Find' function was used to identify the number of times these words or phrases were used. This is a recommended strategy called *in vivo* that adheres to credibility standards in qualitative research (Charmaz, 2006; Mertens, 2015). The words and phrases were compared for similar meanings and added to a new table. Lastly, a constant comparisons analysis was completed using participant-to-participant tables, review of the literature, and other collected data to align meaning and answer each research question.

Results

The purpose of this study was to: (a) explore reasons for CTE teacher preparation program sustainability; and (b) to identify ways to sustain these programs through the perceptions of past and present CTE teacher preparation program educators and administrators. Data analysis resulted in emerging thematic categories based on the participants' perceptions and experiences. Meanings were theoretically constructed from the data with constant comparison between the participants, the researcher's notes, and the literature (Charmaz, 2006). Each word instance was constantly compared to ensure the meaning of the phrases were similar, saturation of the data occurred, and themes emerged from the data. The themes' meanings best represented similar words and phrases that were either vague or misleading.

The key findings were organized by research question. Each research question was answered by either an internal or external domain. Research Question 1 was answered by four categories that work together as a continuous and equal pattern for sustainability. These are areas that the participants felt were controlled by them, or internally controlled. Research Question 2 was answered by three categories participants felt were outside of their control but were important for program sustainability, or externally controlled.

Research Question 1 (internal domain). The first research question addressed perceived program experience. The internal domain categories revealed rationalized strategies the faculty and administrators put into place to help sustain the program. The four categories in the internal domain for research question 1 include: (a) statewide exposure; (b) intracampus alliance; (c) innovative changes; and (d) program ownership.
Statewide exposure. Statewide was mentioned only six times, but the word "community" was mentioned 110 times. Most often, "community" meant CTE teacher preparation program stakeholders throughout the state. Stakeholders included school districts, associations, state colleges, technical centers, advisory boards, external committees, conferences, or industry student competitions. Since the word "statewide" represented the location of the many different stakeholders, it was felt to be a better representation of the meaning than the word "community", which can have many meanings. The word "exposure" was only mentioned twice. However, this word best represented the participants meaning for recruitment. Whenever the participants went out into the community, they were recruiting for their program. "Everyone always has their recruitment hat on" (D. Harris, personal communication, January 27, 2017). Therefore, *statewide exposure* best represented how to sustain a program through statewide promotional efforts.

Intracampus alliance. This phrase was developed from a question in the interview protocol: Who within your institution's administration is an advocate for your program and how does that person support you? The word "support" was mentioned 124 times in the data, which had many meanings. Szuminski's (2003) Components for Development Model also includes "Continuous emotional/psychological and instructional support" (Szuminski, 2003, p. 1). The meaning indicated the ability to show value to administration or other college/department personnel in return for support or acceptance. "You go across campus. You have to be able to work across" (D. Lewis, personal communication, February 1, 2017). Therefore, the term "intracampus" allows for a clearer description of where the support occurs. The second word "alliance" explains the type of relationships with other departments, other colleges, and administrators within the university. Therefore, *intracampus alliance* was a phrase derived from the participants' meaning.

Innovative changes. The word 'innovative' was mentioned only five times. However, 'innovative' represented the clever strategies most of the participants used to keep their CTE teacher preparation programs active. One participant explained how they restructured the program when the enrollment numbers were low, "We offer classes every other year to get our numbers back up to that 18 to 20" (D. Smith, personal communication, January 27, 2017). The ability to anticipate issues and develop ways to reform, revamp, or revise the program in innovative ways is a strategy for sustainability. Thinking about solutions for challenges and issues in ways that do not burden the program is a way to sustainability.

Program ownership. Ownership was used a few times by one participant. "You have to have passion for what you are doing. Ownership… ownership of the program" (D. Lewis, personal communication, February 1, 2017). However, it is a word that best explains many of the other more generic terms that appeared in the data such as value (listed 39 times), pride/proud (listed eight times), respect (listed 16 times), cares (listed 18 times), and succeed (listed nine times). Together, these words are listed 90 times, but represent ownership.

Internal domain conclusion. An internal domain framework of thematic categories is represented. The four categories work together as sustainability strategies for CTE teacher preparation program faculty and administrators as shown in Figure 1.

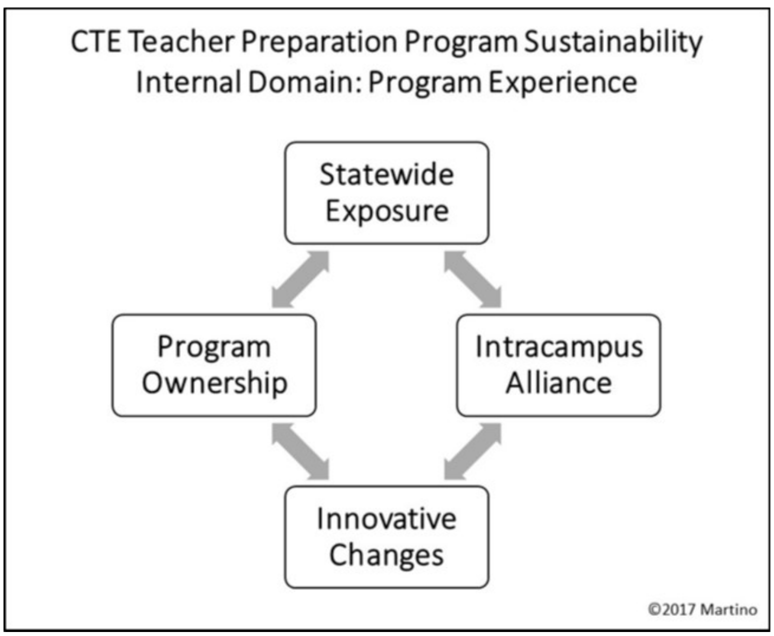

Figure 1

Research Question 2 (external domain). The second research question addressed conditions that were essential for sustainability. Because the essential conditions were perceived necessary for sustainability, the discussion began with challenges. The external domain categories revealed issues that program administrators and faculty may be able to improve through community outreach and education. Three main categories developed from the data are: (a) program value, (b) certification alignment, and (c) employment policies.

Program value. Participants mentioned it was necessary to have institutional administrators who value the program. It was noted that showing value is a great strategy for sustainability, but having the institutional administrators accept the program's value is another matter. Issues emerged to further define ways external stakeholders can affect program value: (a) misinformation; (b) different teacher certifications; and (c) underfunded, understaffed, and underappreciated.

Misinformation occurs when administrators do not understand the program or its needs. Participants stated there is misinformation regarding the value of CTE and the effects the CTE teacher preparation program have on the economy in educating the workforce. A participant retold a story of his administrator's observation in his class.

> "By the way, when are you going to teach?" I realized he didn't know what teaching was, teaching lab. My answer to him was "What do you think I've been doing this whole period since you've been here?" He said, "No, I mean when are to going to lecture?" because to him that was teaching. (D. Clark, personal communication, February 1, 2017).

Two teacher certifications exist in Florida: initial teacher certification and alternative certification. The participants who work in an initial teacher certification program expressed frustration at the certification process and may be misinformed on alternative CTE education degree programs. "They have the content knowledge, but they don't have the pedagogical knowledge" (D. Miller, personal communication, February 2, 2017). The CTE teacher preparation initial certification program enrolls students who learn content and professional education knowledge. Upon graduation, they receive a Florida teaching certificate. The alternative CTE teacher preparation program enrolls students who have experience in the field and take additional content knowledge courses along with professional education courses. After graduation, potential CTE teachers may apply for a teaching license.

Another way participants expressed insufficient program value was through understaffed programs. CTE programs are statewide; therefore, there are heavy travel and recruitment responsibilities. "I know that one of the recommendations of the program evaluators was that we should have another full-time person…" (D. Young, personal communication, January 31, 2017). Additionally, a trend within misinformation is hiring non-CTE personnel for their programs. "I'm concerned that the program is going to suffer when she's gone. Unless we get someone in there who really knows the program, understands the history behind it, understands the students…" (D. Martin, personal communication, January 31, 2017).

Certification alignment. In Florida, there are only two active state-approved CTE initial teacher preparation programs. Some participants stated one of the reasons for low enrollment is the way the State regulates the teacher certification requirements. In state-approved initial certification programs, students are required to pay for and pass three state certification exams before they can take the corresponding courses. The exams include: (a) subject area test; (b) professional education; and (c) general knowledge. "He made it through all three except the professional. He missed it by two points. He just had to take it over again and then he passed" (D. Miller, personal communication, February 2, 2017). According to the Florida DOE website, the General Knowledge Test (GK) is $130 and retake is $150; the Professional Education Test is $150, and the retake is $170; subject area examinations are $200 each and the retake fee is $220 each (Florida Department of Education, 2017).

Employment policies. Effective CTE teachers are in high demand, but there are not enough CTE teacher preparation programs to train them. "We actually have CTE directors and principals that are starting to show up on campus here since January to meet with our students… snatched up as quick as they can" (D. Smith, personal communication, January 27, 2017). One issue for low enrollment may be due to CTE teacher salary, according to some participants. "You see a lot of kids just say it's not worth it. I'll go out into business and get a job" (D. Parker, personal communication, February 3, 2017).

External domain conclusion. An external domain thematic framework is represented in the three categories that work together as a continuous and equal pattern for sustainability. The external domain categories are not controlled by the program faculty and administrators as shown in Figure 2.

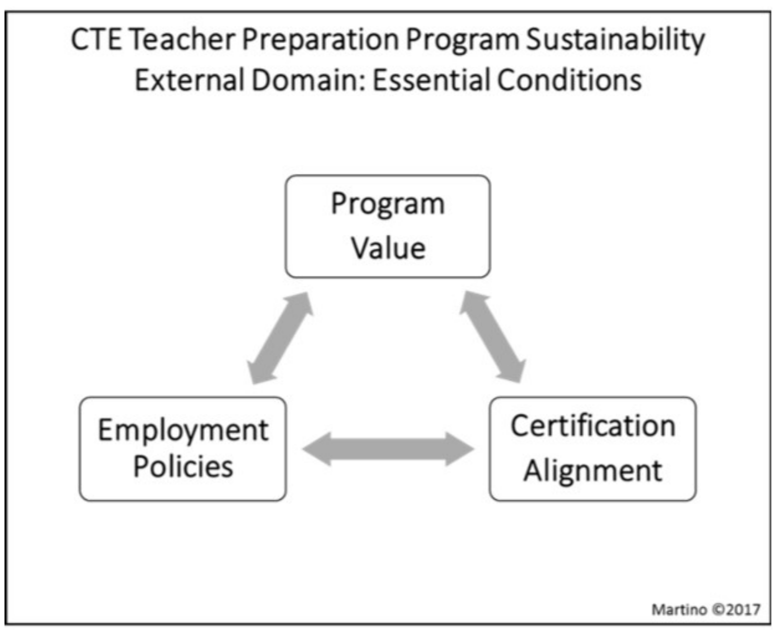

Figure 2

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Summary of the Results
For program sustainability, strategies can be implemented by faculty and administrators. However, external stakeholder support is also necessary. The findings align with the previous studies on CTE teacher preparation programs as well as contribute to literature with a qualitative design. The qualitative design of this study brought about a better understanding of the CTE program participants' experiences, the programs' structures and organizations, and perceived essential conditions for sustainability in a narrative format.

The findings, as a holistic framework for sustainability, perceived by CTE teacher preparation experts include two separate but equal domains: internal and external. One domain is not more important than the other, and the categories within the domains are equally important. Figure 3 shows a graphic representation of the internal and external domains grounded in the research. This final framework graphic represents the equal balance of the internal and external domain categories that should be present for sustainable programs. The arrows balance the bar in the middle that represents the CTE teacher preparation program.

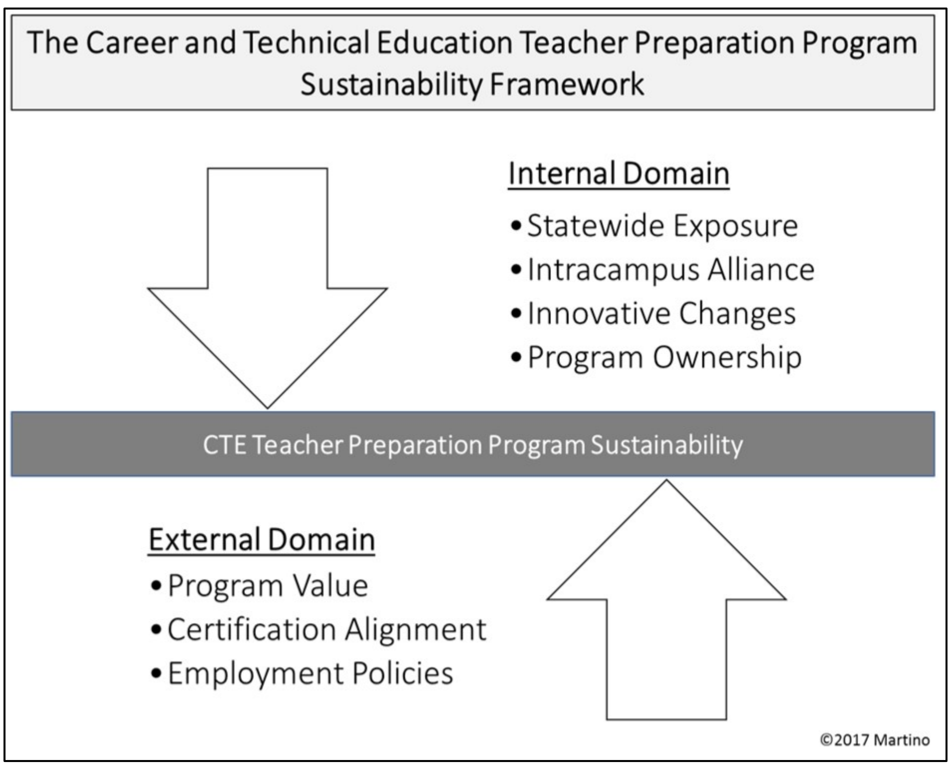

Figure 3

An interesting final finding revealed that CTE teacher preparation programs with higher student enrollments had both the internal and external domain categories in place. The lower enrollment CTE teacher preparation programs had some categories in place. Thus, for a successful CTE teacher preparation program, both domains and all the corresponding subthemes should be used as a guide for sustainability.

Limitations and Implications

Limitations in this study include a small purposeful participant sample and the geographic limitation of Florida state universities. However, the implications for this research are far-reaching. The framework may be used by CTE law makers and stakeholders to create practical policies to support CTE teachers. It can also act as a sustainability roadmap for programs facing possible closure. With that in mind, future research to further this study may include qualitative Grounded Theory studies of external CTE stakeholders, such as Deans, to explore their perceptions of CTE teacher preparation programs. Another qualitative research study involving CTE teaching certification policymakers and their understanding of CTE teacher preparation programs may be useful to assist in the alignment of teacher certification practices. Finally, replication of this study in other U.S. states would be useful to compare the results. In any case, more qualitative research is needed in CTE teacher preparation programs to bring about a deeper understanding and awareness in the issue of program sustainability.

Conclusions and Recommendations

Martino's (2017) study allowed for an investigation of the language, culture, and environment of the participants. The resultant framework has been theoretically grounded in the data. This led to a deeper understanding of the internal and external domains that may have contributed to the decreased CTE teacher preparation programs in Florida. Furthermore, this study aligned with previous program sustainability studies to support the hypothesis of the necessity of internal and external stakeholder support. Therefore, it should be noted that this framework and research design may be helpful to other disciplines for the purpose of a program sustainability study.

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Computer Graphics Applications in the Education Process

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Abstract
Computer graphics have played an important role in information and computer technology studies. It touches many facets of everyday activities: online or offline digital content. Traditionally, computer graphics were studied and researched by computer scientists or programmers to design and develop tools to create graphics and media content. Computer graphics tools and techniques are used by artists for creation of digital artifacts with media rich digital content. With proliferation of various graphic tools, rapid production of new computer hardware capabilities, and cost affordability, educational systems and business enterprises are adopting computer graphics for data visualization, graphical data processing, interactive learning, immersive learning, virtual and augmented reality, presentations, etc. This paper introduces the topic of computer graphics, its history and potential applications of computer graphics, in educational systems that can open new perspective for educators.

Introduction
Traditional forms of art, before the advent of the printing press and mass communication, are paintings, sculpture, and architecture. Development of traditional art form over thousands of years, graphic design, emerged as one of the most advanced forms of visual communication and expression (Kim & Geissbuhler, 2018). According to Hembree (2006), graphic design serves as a method for improving society through effective communication that makes complicated things easier to understand and use. Design helps people, as in how to navigate or assemble something such as assembling drawing, assembly instruction of basic computer, etc. It identifies and informs the public about a wide range of topics, from a company and its products or services. A designer conveys complex ideas in a simple and effective manner (Hembree, 2006).

Advent of computer technologies transformed visual communication media including blueprints, charts, diagrams, schematics, tables, drawings, posters, maps, cartoons, comic books, etc. into a digital form. Visual communication tools are replaced with computer software. Digital graphics created by computer software are called computer graphics.

Computer graphics has got much attention in interactive learning software, multimedia software, online courses and many other applications. It is one of most important component of computer-assisted learning system, which is an educational application area with tremendous potential.

Many students are visual learners; therefore, computer graphics models have the potential to help these students to understand problems that they would not thoroughly understand simply through reading about them or solving word problem. Traditionally, teachers have been using non-computer-based simulations in their classrooms, in the form of science labs and demonstrations. As a result, teachers recreated and modeled these situations using hands-on materials and props. This approach has many disadvantages as it requires extensive labor work, necessary participation of a larger number of people to show the demonstration and it could take several days. With the advancements in technology and computer graphics methods and tools, educators can create virtual objects that obey the laws of nature. These tools allow users to save time and effort by conducting virtual experimentation.

A Brief History of Computer Graphics

The term "Computer Graphics" was coined in 1960 by William Fetter, a graphics designer for Boeing. This term has been recognized as common language following the publication of Ivan Sutherland's PhD thesis on the Sketchpad program at MIT (Sutherland, 1964). Computer Graphics can be defined as use of computers to create and manipulate digital images. Sutherland's Sketchpad was the first fully functional interactive Graphical User Interface (GUI) for drawing primitives such as lines, circles, and polygons and perform operations such as clipping and zooming on those primitives with the use of a light pen. Through the invention of Sketchpad, Ivan Sutherland became known as the "Father of Computer Graphics." Although Sketchpad ran on outdated technology in the form of a 64KB Lincoln TX-2 computer and a monochrome Cathode Ray Tube (CRT) monitor, it grabbed the attention of many researchers for exploring the possibilities of GUI. While the first iteration of Sketchpad was strictly 2D, a few years later Timothy Johnson released Sketchpad 3.0 which expanded its capabilities into three dimensional formats (Johnson, 1963). The CRT display was divided into four familiar views which are widely known today as orthographic front, top, side and perspective. Following the invention of Sketchpad, Sutherland developed the first head mounted display, Sutherland, 1968), which replaced the initial camera device with computer generated images that allowed for remote viewing. This device is now widely known as a virtual reality device. Later, Sutherland's work on hidden-surface removal algorithms gained significant recognition because it solved critical problems in rendering and display technology (Sutherland & Hodgman, 1974). Subsequent advancements in raster algorithms made it possible for the implementation of parametric surfaces, hidden surface removal algorithms, and the use of homogeneous coordinates for differentiating points from vectors. These advancements played a foundational role in the development of projective geometry in 3D graphics (Weiler & Atherton, 1977; Catmull, 1986). Over the past decade, the progression in computer hardware, software, and modeling methodologies has expanded the use of computer graphics to a variety of industries.

Computer Graphics in Education System

The term Computer Graphics covers a broad range of content. For example, the computer graphics-related topics can be found in courses related to computer science, architectural design, mechanical engineering design, arts and design, data visualizations, graphical problem solving, computer simulations etc. Thus, the content of computer graphics education depend on the goals and skills of the area of application, as well as the nature of the student's degree program. Computer graphics courses can be categorized into following groups:

a) **Computer Graphics related to Graphics Development**
Computer graphics courses in computer science, engineering and mathematics primarily cover API based programming languages like OpenGL, WebGL, Python for graphics, OpenCV, etc. These courses typically center on the algorithms, methods, techniques, and models that help companies to identify user insights of how specific principles might work.

b) Computer Graphics in Model Designing and Development
Computer graphics courses in engineering that relate to computer-aided drafting include teaching graphics software like AutoCAD, FreeCAD, Autodesk Inventor, SolidWorks, AutoCAD Architecture, etc. These courses teach how to design components in electrical, mechanical, electromechanical, and electronic devices those necessary for building automobile bodies, civil structures, airplane, ships, optical systems.

c) Computer Graphics for Arts, Games, and Graphics Design
Computer graphics for arts, movies, games, and graphics design courses includes teaching software like Photoshop, InkScape, GIMP, Autodesk Maya, Blender, Cinema 4D etc. These courses primarily teach how to use graphical tools to create and manipulate artistic or computer-generated images. Such images are generated for movies and games, and used in the advertisement of products and services.

d) Computer Graphics for Data Scientist (Simulations and Visualization)
Computer graphics for data analytics courses includes teaching programming languages like Python and, R, and software tools like MatLab, Tableau, Infogram, ChartBlocks, and Datawrapper. These courses employ statistical methods and tools to find interesting patterns among data.

Computer graphics learners studying in the above in the above categories develop customized tools and packages for a wide variety of applications. Several applications are discussed in the following section.

Application Areas of Computer Graphics

With the advent of computer technology, computer graphics has been widely adopted. Traditionally, computer graphics were used to visually represent realistic images in a computer system. Computer graphics are now used as a communication medium to express ideas that either can't be communicated using words or are easier to understand when presented using visual imagery. These days, computer graphics are used in many facets of everyday activities to improve the quality and speed of the user's work. This increased efficiency has been aided by the rapidly increasing power and flexibility of consumer graphics hardware. hardware. Today's standard PC has the capability to render very complex 3D scenes. Through the effort of researchers and developers who design efficient algorithms, users are now able to carry out a wide range of visualization tasks (Ganovelli, Corsini, Pattanaik, & Benedetto, 2015). Additional application areas are discussed below.

Computer Graphics as Communication and Presentation Medium

Computer graphics are used in web design which is the skill of designing presentations of content usually with hypertext or hypermedia. This content is delivered to end-user through the World Wide Web (WWW), with the aid of a Web browser. The process of designing web pages, web sites, web applications or multimedia for WWW may involve multiple disciplines, such as animation, authoring, communication design, corporate identity, graphic design, human-computer interaction, information architecture, interaction design, marketing, photography, search engine optimization, and typography.

Computer Graphics in Entertainment, Games, and Creative Art

Computer-generated images are used for movie making, video games, and the design of catalogs and other commercial arts. Most Hollywood movies are shot inside a studio room in front of blue or green screens known as background plates. These colored plates are replaced with computer generated imagery or overlapped with other real images (often, with many layers) during the post-production stage. This work is made possible using software like Adober After Effects, Nuke, Cinema 4D, etc. This technique, known as Visual Effects (VFx), significantly cuts the cost of movie making because the background plates can be replaced with virtual environments or stock footages available from the internet. Accessing this technology is significantly less expensive than filming on live locations or on mock studio sets. Computer generated images used in games, however, these images are generated and rendered in real-time based on how a player moves during the game. A more current technology, known as Virtual Reality (VR) allows users to interact with a computer-simulated environment with a head-mounted. The simulated environment can be made to feel like the real world when designed for virtual tourism or simulations for pilot or combat training. Virtual Reality has been used to describe a wide variety of applications, commonly associated with its immersive, highly visual, 3D environments. Video games are played in highly immersive 3D environments with commercially available VR headsets like the Samsung Gear VR, HTC Vive, and Microsoft HoloLens (augmented reality). Computer graphics is also widely used in image processing. For example, computer graphics can be used to color grade movie shots to ensure uniformity of lighting between scenes. It is also used for generating 3D models from a set of 2D images, which is the reverse process of getting 2D images from a 3D scene (Moons, 2008). Computer graphics are to create art on a computer in digital form. The impact of digital technology has transformed traditional activities such as painting, drawing and sculpture with drawing and painting on a tablet, or creating and sculpting a model with 3D graphics software like Maya and Blender.

Computer Graphics as Designing Tool

The area of design and drawing was one of the earliest and most useful application areas of computer graphics. In all areas of engineering, civil, mechanical, electronic, etc., drawings are said to be the language of engineers. The ability of computers to store complex drawings and display them on demand triggered the development of Computer Aided Design (CAD) software. Using CAD software, results from engineering calculations can be drawn on the screen. If the design needs to be changed, the values of parameters in formulas are modified and the results are immediately seen on the screen. In architectural and landscape visualization, walk through animations are performed in the virtual models before actual construction. The Vegreville egg, a Ukrainian-style Easter egg and a major tourist attraction in Alberta, Canada was the first physical structure designed entirely with CAD (Lesiv, 2010). CAD software such asSolidwork, allows Computer Aided Manufacturing (CAM). While teaming, integrated CAD technology with Computer Numerical Control (CNC) machines, virtual models can now be printed using a 3D printer (Berman, 2013). CAD is also used to produce computer animated special effects for movies, advertising, and technical manuals.

Computer Graphics as Analysis Tool

Due to the proliferation of data (known as big data) in recent times, resulting from the increased use of online websites and social media, computer graphics are being used more frequently in information visualization and data analytics. Information visualization is the study of the visual representation of large-scale collections of non-numerical information, such as files and lines of code in software systems and the use of graphical techniques to help people understand and analyze data. The field of information visualization focuses on ways to convey abstract information. Using the improved processing power of computers, users are able to use information visualization to identify and communicate relationships among data. Data analytics is now an indispensable part of all applied research and problem solving in industry. The most fundamental data analysis approaches are visualization (histograms, scatter plots, surface plots, tree maps, parallel coordinate plots, etc..), statistics (hypothesis test, regression, principal component analysis, etc.), data mining, and machine learning methods (clustering, classification, decision trees, etc.) Information visualization, or visual data analysis, is dependent on the cognitive skills of human analysts but it allows for the discovery of interesting patterns among data. Analysts do not have to learn any sophisticated methods to be able to interpret the visualizations of the data (El-Assady, Sevastjanova, Keim, & Collins, 2018). Visualization of large text data has applications in domains like stock exchange, ecosystem modeling, and space research.

Computer Graphics in Biology and Medicine
Along with the increased accessibility of hardware technology and interactive devices, the use of computational simulation graphical models began to rise in the field of biology and medicine. A computer simulation model also known as a computational model is a computer program, or network of computers, that attempts to simulate an abstract model of a system under study. These computational models offer the speed necessary to simulate and visualize models at interactive or close-to-interactive rates.

The use of computational techniques increasingly pervades developmental biology, from the acquisition, processing and analysis of experimental data, to the construction of models of virtual organisms and their development with unprecedented visual fidelity. General-purpose mathematical software (e.g. Mathematica and Matlab), modeling programs (e.g. GFtbox), and more specialized packages for modeling plants (e.g. Virtual Laboratory, L-studio, OpenAlea, and Virtual-Leaf) facilitate model construction (Kennaway, Coen, Green & Bangham, 2011; Prusinkiewicz, 2004; Pradal, Dufour-Kowalski, Boudon, Fournier, & Godin, 2008; & Merks, Guravage, Inze, & Beemster, 2010).

Software tools, such as Virtual Touch software being developed by Sonny Chan at the University of Calgary use advanced interactive computing technologies such as haptic devices to improve medical education and healthcare delivery (Mostafa, Ryu, Takashima, Chan, Sousa, & Sharlin, 2017; Ryu, Dharampal, Mostafa, Sharlin, Kopp, Jacobs, et al., 2017; Won, Hwang, Lim, Cho, Paek, Lossorelli, Salisbury, & Blevins, 2017). Chan's research group primarily investigates computational methods in image analysis, computer graphics, medical visualization, haptic rendering in 3D environments, and immersive simulation that help medical professionals utilize medical image data.

Benefits of Computer Graphics in Education
Some of the major benefits of computer graphics education are:

- It allows virtual experiments to be conducted on virtual models that obeys the laws of nature. An example is the L-Studio/V-Lab for modeling and visualizing plants, developed by Prusinkiewicz (2004) and his research group, which makes it possible to simulate plant development with unprecedented biological and visual fidelity. Such tools can be used to teach difficult concepts and working principles with ease.
- It allows users to create simulation models of natural systems in computational physics, chemistry and biology; human systems in economics, psychology, nursing, and social science; and new technologies to study systems and observe behaviors. (Eylon, Ronen, & Ganiel, 1996; Jimoyiannis & Komis, 2001; & Konieczny, 2016).
- In the plan update from U.S. Department of Education (2017), it discusses benefits of using new technology in education. According to this report, using digital technology including media rich contents enhance interaction and collaboration among educators and learners. It improves learner's performance and increases learner's accountability. It extends learning beyond classrooms through self-paced education.

Students are effective learners when they can learn at their own pace and when they can access digital contents at their convenience. It also helps working professionals to learn and update their knowledge during their free time.

Future of Computer Graphics Applications

Classroom instruction has experienced a shift due to the growth and increased accessibility of digital technologies. Computer graphics technology is evolving and adapting to the latest advancements in hardware and software technologies. The graphics capabilities of computers, connectivity to web-delivered content, and ready access to video mediums, including animated content to augment instruction and interactive educational video games. They have provided considerable potential for application in multiple teaching environments and in unlimited course contexts. The recent emergence of online and offline courseware, including massive open online courses (MOOC), has provided for an immersive computer-based environment with opportunities for self-paced learning. Several online courses are integrated with university curricula and allow users to access useful features like any features like reminders, flash cards, practice quizzes, progress reports etc.

Challenges of Computer Graphics Education

Currently, computer graphics is one of the key components of digital information. Computer graphics have the potential to transform the education system into a modern computer-assisted learning system. Some of the challenges that system reformers face are outlined below:

- The reluctance of educators to adopt new technology (Mumtaz, 2000).
- The cost associated with updating software and hardware (Ali, 2011).
- Rapid technological development makes it difficult for educators to keep abreast of changing tools and methodologies (Ali, 2011).
- A need for course content to reflect current information.
- Most educators with non-computer science background lack education or training to use technology effectively in their teaching (Mumtaz, 2000).

Conclusion

This paper outlined the development of computer graphics technologies and various applications in the educational environment. Computer graphics has grown over the past decade tremendously due to the advancements in algorithms, hardware, and software technologies. After working to address any local challenges, educational systems can employ computer graphics to enhance meaningful and flexible learning opportunities for students.

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