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Article

Transitioning to Success: The Link between E-CTE and College Preparation for Students with Learning Disabilities in the United States

Jay S. Plasman [1,*], Filiz Oskay [1] and Michael Gottfried [2]

1 Department of Educational Studies, The Ohio State University, Columbus, OH 43210, USA; oskay.2@buckeyemail.osu.edu
2 Graduate School of Education, University of Pennsylvania, Philadelphia, PA 19104, USA; mgottfr2@upenn.edu
* Correspondence: plasman.2@osu.edu

Abstract: In recent years, there has been a specific call to not only increase the number of engineering-trained individuals but also to address the lack of diversity in science, technology, engineering and mathematics (STEM) fields, including individuals with disabilities. In particular, students with learning disabilities (SWLDs) make up a large portion of all students and are, therefore, a crucial population on which to focus educational and career progression efforts. One potential means of promoting persistence along the STEM pipeline—engineering specifically—is through engineering career and technical education (E-CTE) coursework in high school. Using a nationally representative dataset, we explore how E-CTE participation links to college preparation and transition activities for SWLDs, including math SAT performance, dual credit course participation, college application, and FAFSA completion. Under our more rigorous school fixed-effects models, we find that E-CTE participation is associated with beneficial results across each of our outcomes. The implications are discussed.

Keywords: career and technical education; students with learning disabilities; college preparation; high school; engineering

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1. Introduction

Over the next ten years, a significant increase is expected in the demand for engineering jobs both globally and more locally in the United States, with some specific fields in engineering projecting increases of up to 14 percent [1]. However, in contrast to this growth in engineering job opportunities, there has been an observable decrease in the number of college students enrolling in science, technology, engineering, and mathematics (STEM) subjects and majors [2]. Given these two inverse trends, the United States may not be able to meet necessary labor market demands in engineering [3]. Therefore, it is imperative to address growing concerns regarding the leaky pipeline of students into these fields [4].

In addition to these general concerns, in recent years, there has been a specific call to address the lack of diversity in STEM employment. Increasing STEM diversity within the overall workforce is an important consideration as it allows companies to approach problems through different approaches and to maintain a strong organization [5]. Specifically related to STEM fields, increased diversity can have positive influences on creativity, innovation, and productivity. Further, research has identified financial benefits related to increased diversity [6]. For example, companies with more diverse administrative teams have higher overall revenue compared to those that lack diversity in this area [7]. To achieve these benefits associated with increased diversity in engineering fields, a first step would be to improve the engineering pipeline from high school and into college (i.e., postsecondary education).

Included in the rhetoric about increasing diversity is the attention paid to those individuals with disabilities [8], i.e., the focus of our current investigation. This group has received attention given that individuals with disabilities have lower overall educational attainment in engineering than their peers without disabilities [9]. A vast majority of individuals in engineering careers have at least a bachelor's degree (more than 80%) in this or a related field, and thus, an engineering career is grounded in going to college [10]. Given the consistent, proportionally lower educational attainment of individuals with disabilities and the practical necessity to have at least a bachelor's degree to find work in an engineering field, there is very likely a substantial underrepresentation of individuals with disabilities in engineering careers given the disparities in college-going rates (and subsequent disparities in engineering-major rates). Therefore, the college-to-career pipeline appears to be leaky for individuals with disabilities and thus merits further explanation.

Attending college thus appears to be a critical factor for STEM pipelines, among other outcomes. In this study, we seek to understand if STEM factors might help SWLDs manage the crucial transition period between high school and college [11–13]. Existing research suggests that students who engage in and do well in high school STEM courses (i.e., science, technology, engineering, and mathematics) have a better chance of attending and succeeding in postsecondary education and employment [14,15]. Perhaps then, high school STEM coursework is a key starting point to understanding the scaffolding that leads to SWLDs' enrollment in college and, eventually, pursuits once there. Our study focuses specifically on this former component—enrollment in college—and seeks to examine if this was supported by STEM coursework.

One understudied area of STEM coursework is engineering and technology-focused career and technical education (E-CTE). With the hands-on and practical instructional aspects of CTE generally, we propose that E-CTE courses employ instructional strategies that better align with recommended learning strategies for SWLDs and thus support SWLDs' educational pursuits [16]. In this study, we thus explore how E-CTE coursetaking in high school may relate to a set of key college readiness and preparatory measures. To this end, we asked the following research questions:

a. For SWLDs, how does E-CTE coursetaking in high school link to college preparation outcomes?
b. For SWLDs, how does E-CTE coursetaking in high school link to college transition outcomes?

1.1. Understanding E-CTE in the United States Context

CTE, broadly speaking, is legislated at the federal level in the United States by the *Carl D. Perkins Act* (now in its fifth iteration, aka *Perkins V*). This most recent reauthorization builds off prior versions that emphasize the importance of inclusion of students from special populations, such as those students identified as having disabilities, in CTE programming [17]. While CTE in the United States is often associated with vocational education and training (VET) in the international sense, it is not identical [17]. Similarities include directly focusing on occupation-specific training and preparation for entry into the labor market through coursework delivered as part of a larger career pathway, a career-focused program, or a vocational training center. However, this need not be the case in the United States, as students may also simply choose to take CTE coursework as elective credit in a standalone course.

Nationally, about 85% of students participate annually in CTE programming, with approximately 98% of secondary schools offering CTE programming [18,19]. However, unlike in the international context, only 12% of students are fully enrolled in career training centers for secondary school, which contrasts starkly with other nations: 42% of students in the UK; 59% of students in Germany; 64% of students in Switzerland; and 25% of students in Japan [20]. Further, the apprenticeship system in the United States is not formalized within the education system as it is in many other nations.

A key provision of *Perkins V* is the emphasis on instruction of STEM skills and knowledge through an integrated technical and academic curriculum. STEM-focused CTE courses are, by design, meant to help students develop and apply math and science skills through practically relevant and engaging instruction [21]. These courses are meant not only to teach practical, occupation-specific skills but also to provide students the opportunity to develop quantitative reasoning, logic, and problem-solving skills that are of relevance in both college and career pursuits [22].

E-CTE represents one strand of STEM-focused CTE coursework. Examples of such courses include surveying, structural engineering, and computer-assisted design. Through participation in these courses, students gain the necessary skills and education to excel and persist in STEM-related areas by completing rigorous projects related to engineering design, manufacturing process implementations, and quality improvements [23]. Importantly, E-CTE courses are not intended to replace traditional, academic STEM courses (e.g., physics or algebra II) but are instead meant to complement the material and reinforce the conceptual and academic knowledge from these traditional STEM courses [24,25].

Educational Benefits of E-CTE

There is a growing body of evidence regarding the efficacy of STEM-CTE coursework with respect to promoting beneficial outcomes across secondary, postsecondary, and labor market contexts. In secondary education, students who participate in STEM-CTE exhibit higher levels of self-efficacy and school engagement, have better attendance, are more likely to take advanced STEM courses, have higher math achievement scores, and are more likely to graduate high school [24,26]. Furthermore, there is evidence that STEM-CTE coursework is particularly beneficial to SWLDs, above and beyond the benefits for general education students, with respect to high school graduation, earning industry-recognized credentials, and mathematics achievement [27].

In addition to benefits in high school, E-CTE coursetaking specifically links to later positive outcomes related to postsecondary education and career. For example, Gottfried and Plasman [28] found that students in the general population who take E-CTE courses in high school are more likely to go on to earn a postsecondary engineering credential. Beyond E-CTE, students who earn a STEM-CTE credential in a two-year college are expected to have higher earnings once they enter the labor market compared to those who earn non-CTE credentials [29]. In the broader sense, CTE also appears to benefit SWLDs with respect to improving postsecondary participation and labor market prospects [30,31].

There is reason to believe that STEM-CTE, and E-CTE specifically, may be of particular benefit to SWLDs. Traditional STEM coursework may be especially difficult for many SWLDs, given its abstract nature [32,33], and E-CTE courses provide opportunities to connect theoretical knowledge with practical skills [34]. Importantly, the pedagogical methods implemented in E-CTE courses align much more closely with suggested accommodations for SWLDs—use of multiple senses, hands-on and lab experiences, and numerous demonstrations by the instructor [35,36]. Through E-CTE coursework, students can evaluate their own emerging scientific knowledge and use it to solve practical problems, thereby improving their understanding and interest in STEM fields [37]. E-CTE coursework may also make learning more meaningful since these courses are specifically designed to support students in understanding the work of engineers by highlighting the link between coursework and later opportunities [37,38]. Ultimately, E-CTE coursework likely supports SWLDs through improved alignment with learning accommodations in reinforcing academic skills, developing new skills, and highlighting the relevance of high school coursework, thereby helping them better learn and engage with STEM-related subjects and ultimately enhance their motivation to succeed and persist along the STEM pipeline [39,40].

Despite these empirical findings and the growing evidence supporting the benefits of STEM-CTE, little is known regarding how E-CTE, in particular, may support college preparation for SWLDs. Therefore, a significant 'node' on the STEM pipeline has been overlooked—namely, the transition from high school to college.

1.2. College Preparation and Transition

Although it is difficult for any student to make a smooth transition from secondary to postsecondary settings, these changes can be particularly dramatic for SWLDs [41,42]. This group of students tends to be less prepared to succeed in college, particularly in STEM areas, due in part to lower levels of participation in STEM coursework in high school [43,44]. This gap in high school STEM participation and success is associated with lower levels of STEM readiness and results in a lower likelihood of pursuing and persisting in STEM fields [33,45]. We explore college preparation through performance on the math section of the SAT (i.e., an entrance examination required by many postsecondary institutions) and participation in dual credit coursework (i.e., courses for which students earn credit both at the secondary and postsecondary levels). We examine college transition through indicators of whether a student applied to college and whether they completed the FAFSA (i.e., the Free Application for Federal Student Aid—a required document if students wish to receive financial aid to attend a postsecondary education institution).

E-CTE and College Preparation and Transition

Over a lifetime, it is estimated that a 4-year college graduate will earn 84% more than a high school graduate [46]; thus, postsecondary education has a strong relationship with future opportunities. While college enrollment rates for students with disabilities have been increasing overall, they still lag behind the rates for students without disabilities [47,48]. In response to these concerns, prior research has established that participation and success in high school STEM coursework are significant factors in students' decisions to continue along the STEM pipeline [33,49,50]. As an empirical illustration, about 80% of students who completed STEM degrees decided on their majors in high school [14,51]. With respect to SWLDs, work by Author [21] supports a potential connection between CTE coursework and college application, as findings showed that SWLDs who participated in CTE coursework were more likely to enroll in college than those who did not participate in CTE.

Prior work on STEM-CTE coursetaking in [23] highlights three potential mechanisms by which these courses may link to the following benefits: reinforcement of academic skills, new skill development, and relevance and engagement. With respect to academic skill reinforcement, CTE coursework is meant to integrate academic and technical skill learning [24]. Through participation in E-CTE coursework, students are provided the opportunity to build on learning from traditional STEM coursework through more applied and hands-on experiences [24,25]. This complementary aspect of E-CTE coursework can help boost STEM achievement [21,23], which may then ultimately link to success on standardized tests—one predictor of college enrollment and success [52]. Various studies have indicated that completing more STEM courses in high school links to higher SAT scores [53–55]. This finding holds for SWLDs as well, such that SWLDs who completed more STEM credits achieved higher math proficiency scores [11]. Given the nature of E-CTE coursework to reinforce academic STEM learning, there is reason to believe these courses may benefit SWLDs with respect to performance on the SAT. This hypothesis is supported by prior work by Author [21] showing that SWLDs who participated in STEM-CTE coursework exhibited higher scores on standardized math tests, though college preparatory exams were not studied.

The second mechanism is new skill development. With respect to E-CTE participation, the learning that takes place in these courses may help students acquire the skillsets necessary to succeed in both college and career. Specifically, using multiple learning techniques to teach these skills is an important pedagogical method to help students understand their abilities and encourage interest in future pursuits along the engineering pathway [56,57]. As such, E-CTE coursework may help students gain new skills that will be essential for success in college, thereby encouraging students to complete the preliminary steps in the pursuit of a postsecondary education, such as completing the FAFSA. Considering the difficulties SWLDs encounter in traditional STEM courses, E-CTE courses are specifically beneficial for them with the help of the pedagogical approaches they use to connect theory and practice [34,40]. Thus, SWLDs may see additional support through participation in E-CTE courses toward developing the skills necessary to pursue postsecondary education. FAFSA completion is an essential step in the transition to college since financial considerations are cited as one of the main barriers to attaining a postsecondary degree [58]. Existing literature has established that by lowering the costs of attendance, financial aid plays an effective role in increasing access to college and also promotes persistence [59–62]. In their three-phase college decision-making model, Hossler et al. [63] identify students' FAFSA decisions to help defray attendance costs as a significant factor in college attendance. Completing a FAFSA may have more significant importance for SWLDs' college enrollment because adolescents with learning disabilities are more likely to come from lower SES families compared to those without learning disabilities, suggesting a higher need for financial assistance [64].

Finally, E-CTE participation is likely to emphasize the relevance of coursework and encourage engagement with school and learning. Again, the applied nature of CTE coursework in high school is designed to help students make the connection between high school coursework and later opportunities in college and career [65]. Though relevance is a difficult concept to measure empirically, students who participate in STEM-CTE courses and career-related activities in school demonstrate higher levels of engagement as measured by attendance, high school completion, and behavior [66–68]. Relatedly, students' engagement in science and engineering through CTE coursework may also encourage them to participate in dual enrollment coursework—courses for which students receive credit in high school as well as credit toward postsecondary progress—a category of coursework into which many CTE courses fall [69]. Dual credit course participation is associated with a number of benefits. For example, students who participate in dual enrollment courses are more likely to attend college immediately after high school [70] and are more likely to attend college as full-time students [71]. Additionally, dual enrollment courses directly prepare students for college through participation in college-level coursework [72,73]. Recent work by Corin et al. [74] indicated that students who participated in STEM dual enrollment courses had a significantly higher probability of declaring an interest in STEM careers by the time they graduated from high school compared to their peers who did not take dual enrollment courses. Despite the potential difficulty in measuring relevance directly, student decisions to persist along a chosen pathway (e.g., STEM) can serve as a proxy measure. As students see the relevance of a given field of study—in this case, engineering—they are likely more inclined to want to persist along that pathway into further education and completing the necessary steps in college preparation. As such, through participation in E-CTE coursework, SWLDs may be encouraged to earn dual enrollment credit by participating in more E-CTE courses, thus, score higher on standardized math test scores, be more likely to apply to college and be more likely to complete the FAFSA.

2. Methods

2.1. Data

To respond to our research questions, we used a longitudinal dataset representative of the United States population created by the National Center for Education Statistics (NCES): the High School Longitudinal Study of 2009 (HSLS). This dataset followed a cohort of students who entered the 9th grade in 2009 through high school and into postsecondary education and early career. Importantly, this is the most recent dataset that includes representation across the full nation, for which there is secondary school coursetaking data and key information at the postsecondary level. In addition to the baseline survey in 2009, NCES conducted follow-up surveys in 2012, 2013 and 2016. Due to data collection from students, parents, administrators, teachers, and school counselors, this dataset provides a robust snapshot of each student over time. Given the nature of the existing data, our study received an institutional review board (IRB) exempt status.

To complement survey data, NCES collected full high school transcripts across the 2013–2014 school year. These transcript data contain full high school coursetaking histories for each student. In addition to each course taken, this dataset also included credits and grades earned and course codes to identify each unique course. Course codes, based on the school courses for the exchange of data (SCED) codes developed by the National Forum on Education Statistics, were key to this study as they allowed us to identify courses falling into the E-CTE, other CTE, and academic course categories. Course credits have been standardized to Carnegie Units by NCES to ensure comparability across different schools. Under this process, one Carnegie Unit is defined as one hour of class time every day over a full school year.

The full sample across the HSLS dataset includes more than 23,000 students from more than 900 secondary schools. Based on our research questions, we restricted our analysis to focus on those students identified as having a learning disability who had non-zero weights. This resulted in a final analytic sample of 870 SWLDs. In alignment with NCES guidelines, we report sample sizes rounded to the nearest ten. We included student-level weights identifying membership in the baseline, first follow-up survey, and inclusion of transcript data to ensure sample representativeness. We approached issues of missing data by imputing 20 additional datasets as recommended in prior methodological work [75].

Our study focuses on the differences in E-CTE coursetaking behavior for SWLDs. We identified SWLDs using an item from the base year parent survey that asked parents whether they had ever been told by a doctor or other professional that their child had a specific learning disability. We used this definition as opposed to the administrative records relating to individualized education plans due to the high percentage missingness on the IEP variable. This approach has been used in prior research on SWLDs [76].

2.2. Outcomes

2.2.1. College Preparation

To assess the relationship between E-CTE participation and college preparation, we identified two outcomes known to be associated with later success in college. Here, we focus on math SAT scores and dual credit course participation. Math SAT scores were pulled directly from the HSLS dataset, and students' scores were identified on a continuous scale from 200 to 800. Dual credit course participation is a binary indicator identifying whether a student ever earned credit in a dual enrollment course.

2.2.2. College Transition

We also identify two outcomes related to the transition process from high school to college. Specifically, we examine applications to college and FAFSA completion. We define college application as a binary variable indicating whether a student has ever submitted a college application. Finally, FAFSA is also a binary variable indicating whether an individual ever successfully completed a FAFSA.

2.3. E-CTE Coursetaking in High School

As mentioned above, the NCES transcript data includes course codes for every course a student participated in during high school, as well as the number of credits earned and the year in high school those credits were earned. The codes allowed us to identify the number of credits a student earned in E-CTE based on the high school course taxonomy [22]. Within the E-CTE framework are two distinct sets of courses: engineering and technology. We were able to separately identify engineering or technology courses based on course codes. To determine whether there were differences in potential benefits related to participation courses, we analyzed engineering and technology courses as separate entities. Collectively, however, we refer to engineering and technology as E-CTE throughout this article. We operationalized E-CTE coursetaking here as the number of credits completed, which we identify as the number of Carnegie units completed. Across our final analytic sample, students earned an average of 0.17 E-CTE credits. Of those individuals who participated in E-CTE (approximately 14% of our sample), the average number of earned E-CTE credits was 1.18, equivalent to slightly more than two semester-long courses.

2.4. Control Variables

We selected a robust set of control variables to include in our analyses based on prior research on SWLDs in CTE [77]. We include all of these control variables in each of our empirical models to improve and focus our estimates on obtaining a more accurate overall interpretation of the relationship between our independent variable of interest (E-CTE coursetaking) and our identified outcomes of interest. Descriptive statistics for our selected variables are presented in Table 1. The set of control variables are separated into three categories: Sociodemographic variables; academic attitudes and history, and school variables. Our sociodemographic variables include gender, race/ethnicity, family arrangement, socioeconomic status, parent employment in a STEM occupation, and highest parent education. Academic attitudes include the following: expectations for an engineering career; postsecondary expectations; math identity, self-efficacy, and utility; and science identity, self-efficacy, and utility. Each of these attitudes was sourced from the baseline survey. Academic history variables were pulled from the transcript data. Here, we included 9th-grade GPA, total number of academic credits earned (i.e., credits earned in English, social studies, mathematics, and science), number of other CTE credits earned (i.e., not in E-CTE), and whether the student took an advanced math course in 8th grade (i.e., algebra or higher).

Table 1. Descriptive Statistics.

	Mean	**Std Dev**		**Mean**	**Std Dev**
Outcomes			Academic Attitudes and History		
Dual Course Enrollment	0.22	(0.47)	9th-Grade GPA	2.25	(0.84)
Math SAT Score	434.01	(113.87)	Academic Credits	15.46	(6.24)
Apply to College	0.74	(0.44)	Advanced Math in 8th Grade	0.18	(0.38)
FAFSA Application	0.67	(0.49)	Postsecondary Expectations		
CTE Participation			High School or Less	0.42	(0.46)
Engineering Credits	0.17	(0.54)	2 Year Degree	0.10	(0.30)
Other CTE Credits	2.98	(2.78)	4 Year Degree or more	0.48	(0.50)
Demographic Variables			School Variables		
Female	0.38	(0.49)	Percent ELL	4.51	(7.94)
Race/Ethnicity			Percent FRL	37.59	(25.48)
Other Race	0.11	(0.31)	Percent Minority	33.22	(29.29)
Black	0.11	(0.31)	School Climate	−0.47	(1.03)
Hispanic	0.20	(0.40)	Public High School	1.13	(0.33)
Asian	0.02	(0.14)	Urbanicity		
White	0.56	(0.50)	Urban	0.27	(0.44)
Parental Arrangement			Suburban	0.35	(0.48)
Single Parent	0.34	(0.47)	Town	0.12	(0.33)
Both Biological Parents	0.47	(0.50)	Rural	0.25	(0.43)
Other Arrangement	0.15	(0.36)			
SES	−0.13	(0.74)			
N					870

Note: All variables binary unless noted (Math SAT: 200 to 800; Eng. Cred: 0 to 6; Other CTE cred: 0 to 19.5; SES: −1.75 to 0.28; GPA: 0 to 4; Academic Credits: 0 to 53; Percent ELL, FRL, Minority: 0 to 100; School Climate: −4.22 to 1.97).

Our school variables include school demographics such as the percentage of students identified as English Language Learners, the percent of students receiving free or reduced-price lunch, and the percent of students identified as racial/ethnic minorities—Black, Hispanic, and Native American. We also include indicators of urbanicity and a binary indicator of school control. Finally, we included a measure of school climate. This school climate measure identifies the extent of certain problems (e.g., bullying, drug use, vandalism, etc.) at a given school as identified by the administrator on the baseline survey.

2.5. Analysis Plan

To respond to our research questions, we based our estimates on the following model:

$$Y_{ij} = \beta_0 + \beta_1 ECTE_i + \beta_2 X_i + \beta_3 S_j + \varepsilon_{ij}. \quad (1)$$

Here, Y_{ij} is a placeholder for the outcome of interest (e.g., math SAT score, dual credit course participation, application to college, and FAFSA completion) for student i in school j. $ECTE_i$ represents the number of E-CTE courses earned. X_i and S_j represent vectors containing our student and school covariates, respectively. Finally, ε_{ij} represents the error term with standard errors adjusted for high school clustering. This allows us to account for the fact that students are nested within schools. Note that the sample size drops when exploring math SAT scores as an outcome. The SAT sample is smaller as only SAT students were included. Finally, in the instances where the outcome is binary, this model is a linear probability model such that the estimated coefficient represents an expected change in the probability of the outcome occurring.

We used an additional estimation strategy to test the sensitivity of the findings from our main specifications. Specifically, we used school-fixed effects to account for potential omitted school biases that may have influenced the relationship between E-CTE coursetaking and our outcomes of interest. By controlling for each school, this model accounted for any school-specific factors that may have influenced E-CTE participation or any of the outcomes. This could include policies related to services provided to SWLDs, practical issues related to course access, the number of college counselors as a few examples, or the extent to which an engineering program exists at school. Without accounting for such unobservable factors, we may have over- or under-estimated the association between E-CTE and the outcomes of interest. By holding all time-invariant factors (either observed or unobserved) constant at the school level, we were able to focus on within-school variation. We built off our moderation models such that the school-fixed effects model was exemplified by the following equation:

$$Y_{ij} = \beta_0 + \beta_1 ECTE_i + \beta_2 X_i + \gamma_j + \varepsilon_{ij} \quad (2)$$

Here, we replace the vector containing the school variables in our baseline equation with the term γ_j, which represents a vector containing an indicator for each school in our analyses, with one school removed to serve as a reference. Note that all school factors are now accounted for under the fixed effects indicator.

3. Results

3.1. Research Question 1: E-CTE and College Preparation

Recall our first question asked about the relationship between E-CTE participation and college preparatory activities related to achievement and coursetaking. Specifically, we examined whether SWLDs who earned more E-CTE credits were more likely to score higher on their math SAT test or participate in dual credit coursework than SWLDs who earned fewer E-CTE credits. The dual credit course participation variable is binary, so the resulting estimates should be interpreted as the percent change in the probability of dual credit course participation. Table 2 presents the results of these analyses, specifically emphasizing the unique relationship between engineering CTE credit earning and the outcomes of interest. To ease our discussion of results, the numbers in parentheses along the top row refer to the model number. It is worth mentioning again that these analyses focused on the population of students identified as having a learning disability. As such, we are comparing SWLDs who participated in E-CTE to SWLDs who did not participate in (or took fewer) E-CTE courses, and all results should be interpreted as such.

Table 2. High School Achievement and Coursetaking Outcomes.

	(1) Math SAT Score		(2) Dual Credit		(3) College Application		(4) FAFSA	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Engineering Credits	20.17 +	(11.29)	0.08 *	(0.04)	0.04	(0.03)	0.11 ***	(0.02)
Other CTE credits	−1.79	(2.33)	−0.00	(0.01)	−0.00	(0.01)	0.02 **	(0.01)
Sociodemographic Variables								
Female	−31.53 **	(9.94)	0.00	(0.03)	0.04	(0.04)	0.01	(0.05)
Race/Ethnicity								
Other race	7.31	(17.93)	0.02	(0.05)	−0.05	(0.07)	−0.07	(0.08)
Black	−64.53 ***	(17.78)	−0.00	(0.05)	0.05	(0.07)	0.03	(0.08)
Hispanic	−6.72	(14.92)	0.01	(0.04)	−0.02	(0.05)	0.02	(0.07)
Asian	23.54	(26.28)	−0.08	(0.09)	−0.10	(0.08)	0.08	(0.14)
Family Arrangement								
Single parent	9.99	(16.35)	0.04	(0.05)	0.04	(0.06)	0.11 +	(0.07)
Both biological parents	10.92	(15.70)	0.05	(0.04)	0.05	(0.06)	0.07	(0.06)
Socioeconomic status	23.74 **	(8.10)	0.00	(0.02)	0.05 +	(0.03)	0.04	(0.04)
Academic History								
9th-grade GPA	29.89 ***	(6.75)	0.08 ***	(0.02)	0.04	(0.03)	0.03	(0.04)
Academic credits	2.02 +	(1.13)	−0.00	(0.00)	0.02 ***	(0.00)	−0.01	(0.01)
Adv. math in 8th grade	72.24 ***	(13.26)	0.11 **	(0.04)	0.07	(0.05)	−0.09	(0.06)
PSE Expectations								
2 Year Degree	1.79	(22.77)	0.03	(0.06)	0.13 +	(0.07)	0.13	(0.09)
4 Year Degree or more	16.20	(13.87)	0.07 +	(0.04)	0.10 +	(0.05)	0.21 ***	(0.06)
School Variables								
% ELL	−0.06	(0.68)	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
% FRL	−0.85 **	(0.28)	−0.00	(0.00)	0.00	(0.00)	0.00 *	(0.00)
% minority	0.10	(0.24)	0.00	(0.00)	0.00 *	(0.00)	−0.00	(0.00)
School climate	4.19	(6.04)	0.01	(0.02)	0.03	(0.02)	0.02	(0.03)
Public school	−4.61	(16.14)	−0.09 +	(0.05)	0.07	(0.06)	0.12	(0.10)
Urbanicity								
Urban	16.76	(12.83)	−0.08 *	(0.04)	0.04	(0.05)	0.02	(0.06)
Rural	−5.34	(13.08)	−0.04	(0.04)	−0.05	(0.05)	0.01	(0.06)
Town	−11.73	(16.64)	0.08	(0.05)	0.03	(0.06)	−0.05	(0.08)
N		330		870		870		790

Standard errors clustered at the school level in parentheses + $p < 0.10$; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Model 1 in Table 2 identifies the relationship between E-CTE participation and math SAT scores. This analysis found a marginally significant relationship between E-CTE and higher math SAT scores. Specifically, for each additional E-CTE credit earned, students could be expected to score about 20 points higher on the math SAT assessment. This relationship does need to be considered with the caveat that it is only significant at the $p < 0.10$ level. However, the 20-point higher score does translate to an effect size of nearly two-tenths of a standard deviation for each additional credit of engineering a student earned. It is also worth pointing out that the relationship between E-CTE and SAT performance is limited only to those students who do take the SAT—approximately 330 in our sample. As such, any observed relationship should only be interpreted for those students who take the SAT and not as an overall measure of improved achievement across the full sample. Turning next to participation in dual credit coursework, model 2 we did observe a significant relationship with E-CTE participation (0.08, $p < 0.05$; $\delta = 0.07$). This estimate of 0.08 implies that for each E-CTE credit earned, SWLDs had approximately eight percent higher probability of participation in dual credit coursework.

It is also worth briefly mentioning the relationship between some of our identified control variables and our outcomes of interest. Specifically, within the population of students with learning disabilities, female students, Black students, and students from lower socio-economic backgrounds are all expected to score significantly lower on their SAT exams than male students, White students, and students from higher socioeconomic backgrounds, respectively. Additionally, there are a number of academic variables associated with higher SAT scores. Higher grades in the first year of secondary school (i.e., 9th-grade GPA) and students who participated in advanced math coursework were expected to have higher SAT scores. Finally, students attending schools with a higher proportion receiving free or reduced-price lunch were expected to have lower SAT scores. With respect to dual credit earning, only the academic variables related to GPA and advanced math coursetaking were significantly associated with higher odds.

3.2. Research Question 2: E-CTE and College Transition

Next, we turn to our second research question, which asked whether there was any observable relationship between E-CTE coursetaking and secondary-to-postsecondary transition outcomes. Specifically, we examined whether SWLDs who took more E-CTE courses had a higher probability of completing a college or FAFSA application than those who took fewer courses. Given the binary nature of both variables, the estimates shown should be interpreted as the percent change in the probability of observing the outcome of interest.

Model 3 in Table 2 contains the results from our analysis linking E-CTE participation to the probability of applying to college. Here, we found no significant relationship between E-CTE credits earned and the probability of college application in either the positive or negative direction. In this model, academic credits earned were the only observable variable with a meaningful, significant relationship at 0.05. However, in the probability of completing a FAFSA, model 4 provides evidence that E-CTE coursetaking is significantly linked with higher probabilities for SWLDs. More specifically, for each E-CTE credit earned, SWLDs were expected to have approximately 11% higher probability ($\delta = 0.10$) of completing the FAFSA.

There were not many significant control variables. In reference to higher odds of college application, only the number of academic credits earned was meaningfully significant (0.02, $p < 0.001$). In considering FAFSA completion, the only significant student-level factor was expectations for a four-year degree or higher (0.21, $p < 0.001$).

3.3. School Fixed Effects

Table 3 contains the estimates for each of our school fixed effects analyses. Note that school variables are removed as they are held constant via the school fixed effects indicator. Given the potential ways schools may influence E-CTE coursetaking or our outcomes of interest, these estimates are likely less biased than our baseline specifications, though should still not be interpreted as causal. In reviewing our results below, we mention only our variable of interest—engineering credits—in our discussion for parsimony.

Model 1 focuses on math SAT scores as the outcome. Under this estimation strategy, we found that the estimate is significant and is also larger than our baseline estimation (74.14, $p < 0.05$; $\delta = 0.26$). Specifically, for each credit of E-CTE earned, SWLDs were expected to score about 74 points higher on their math SAT assessment.

With respect to dual credit course participation (model 2), each E-CTE credit is significantly associated with about a fifteen percent higher probability ($\delta = 0.10$) of participation for SWLDs. Note that our sample size drops slightly under this estimation strategy. This is likely due to the fact that there was no variation in outcomes at the school level. Model 3 suggests that each E-CTE credit is associated with a thirteen percent higher probability ($\delta = 0.14$) of completing at least one college application. Finally, we also found that E-CTE significantly relates to completing the FAFSA for SWLDs (model 4). Specifically, each E-CTE credit related to a seventeen percent higher ($\delta = 0.15$) probability of FAFSA completion. Again, the sample size dropped slightly in this model as there may have been no variation in outcome at the school level.

Table 3. School Fixed Effects Estimates.

	(1) Math SAT Score		(2) Dual Credit		(3) College Application		(4) FAFSA	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Engineering Credits	74.14 *	(34.66)	0.15 *	(0.07)	0.13 **	(0.04)	0.17 *	(0.08)
Other CTE credits	3.02	(6.68)	0.02	(0.01)	0.00	(0.02)	0.00	(0.02)
Sociodemographic Variables								
Female	−21.72	(25.10)	−0.04	(0.05)	0.05	(0.07)	−0.04	(0.09)
Race/Ethnicity								
Other race	−15.29	(66.52)	0.05	(0.08)	−0.07	(0.10)	−0.07	(0.14)
Black	−43.73	(55.32)	0.01	(0.13)	0.16	(0.15)	−0.06	(0.21)
Hispanic	−26.64	(35.16)	−0.10	(0.09)	−0.00	(0.11)	−0.12	(0.14)
Asian	80.20	(66.85)	−0.15	(0.24)	−0.16	(0.19)	0.07	(0.34)
Family Arrangement								
Single parent	8.82	(39.82)	0.14 +	(0.08)	0.01	(0.11)	0.10	(0.14)
Both biological parents	1.11	(38.22)	0.06	(0.07)	−0.03	(0.09)	0.02	(0.11)
Socioeconomic status	16.43	(19.23)	−0.01	(0.04)	0.10 +	(0.05)	0.01	(0.08)
Academic History								
9th-grade GPA	1.86	(20.59)	0.11 *	(0.05)	0.13 *	(0.06)	0.06	(0.07)
Academic credits	0.39	(4.30)	−0.00	(0.01)	0.02 **	(0.01)	0.03 *	(0.01)
Adv. math in 8th grade	66.36 +	(35.95)	0.16 *	(0.08)	0.02	(0.09)	−0.10	(0.11)
PSE Expectations								
2 Year Degree	20.13	(52.09)	−0.02	(0.12)	0.19	(0.13)	0.22	(0.19)
4 Year Degree or more	41.01	(32.71)	0.06	(0.10)	0.16	(0.10)	0.18	(0.12)
N		330		870		870		790

Robust standard errors in parentheses: + $p < 0.10$; * $p < 0.05$; ** $p < 0.01$.

3.4. Results Summary

To summarize, our results identified a number of benefits for SWLDs associated with participation in E-CTE coursework. Focusing on our more robust school fixed effects estimation strategy, we found that E-CTE coursetaking in secondary school is linked to higher expected SAT scores, a higher probability of earning dual enrollment, a higher probability of applying to a postsecondary institution, and a higher probability of completing the FAFSA.

4. Discussion

For equity, educational, and economic reasons, it is crucial to find ways to encourage participation in and persistence along the pathway from high school to college and, ultimately, to career. Given how important going to college is to the engineering field, understanding the factors that may support students in making the critical transition from high school to college is necessary to address the problem of the low number of STEM and engineering college graduates in the United States [8–10]. It is particularly important to consider the encouragement of participation and persistence for traditionally underrepresented students like SWLDs because, as research indicates, although college enrollment rates for students with disabilities have been increasing overall, they still lag far behind their peers without disabilities [47,48].

By examining college preparation, our study contributes to the field by showing how coursetaking in high school may relate to college-going. Specifically, we explored how taking E-CTE coursework in high school may relate to college preparation for SWLDs. In response to the research questions posed in this study, we found a significant relationship between E-CTE participation and college preparation. First, SWLDs who took more E-CTE scored higher on their math SAT tests than students who took fewer E-CTE courses. Second, we observed a parallel relationship between dual credit participation and E-CTE enrollment.

Turning to secondary-to-postsecondary transition activities, we did not observe a significant relationship between E-CTE participation and the probability of college application for SWLDs under our baseline model. However, we did observe a link between E-CTE participation and the probability of completing the FAFSA, such that each E-CTE credit earned was related to a nine percent higher probability of FAFSA completion for SWLDs. Considering the E-CTE course-taking behavior and high school and postsecondary education outcomes for SWLDs, our study's findings align with the existing research on students in the general population that shows the effectiveness of STEM-CTE coursework in supporting students' transition into and pursuits within postsecondary education. Though the effect sizes associated with each of our estimates may appear relatively small, recent work by Kraft [78] suggests that effect sizes related to education should be interpreted using the following benchmarks: less than 0.05—small effect; between 0.05 and 0.20—medium effect; and greater than 0.20—large effect. Under this schema, we would expect medium-sized effects for most of our outcomes, with a potentially large effect related to SAT scores in math amongst those students who take the SAT examination.

4.1. Implications

Given the positive findings presented in this study, our study presents several important implications for policy and practice. Importantly, SWLDs benefit from E-CTE coursework with respect to a range of college preparation outcomes. STEM-focused career courses such as E-CTE are designed to support students in developing and applying math and science skills through practically relevant and engaging instruction [21]. They aim for more than just improving occupation-based skills; they provide students an opportunity to develop quantitative reasoning, logic, and problem-solving skills that are useful in college and career pursuits [22] and their individual development. However, the efficacy of E-CTE courses in meeting the expected goals is closely related to the quality of the in-class experiences and the accessibility of such courses to all students. With this in mind, there are two important considerations. First, it is necessary to ensure educators are aware of how E-CTE's unique features may benefit SWLDs and acknowledge that SWLDs can succeed in these settings. Additionally, providing counselors with the tools to best advise SWLDs with respect to E-CTE participation as a way to promote the relevance of coursework and develop an interest in STEM is an essential factor in the success of E-CTE courses. Thus, future policies and interventions may turn to the training of E-CTE educators (both teachers and counselors) to help them understand the logic of the courses with a specific focus on best practices in relation to interactions with and instruction of SWLDs.

Second, we found that E-CTE participation positively relates to college application and FAFSA completion behaviors of SWLDs. Policymakers should consider these findings as they seek ways and policies to promote E-CTE fields in postsecondary education. E-CTE courses offer a potential means of increasing participation in STEM majors. In order to meet the demand of the market, our study helps education policymakers understand the connection between SWLDs' E-CTE course enrollment and the objectives for increasing the pursuit of engineering degrees. This deeper comprehension will help guide policies encouraging short- and long-term STEM persistence.

Finally, a further examination of the lower numbers of SWLDs in STEM fields necessitates focusing on the college preparation, dual credit enrollment, and SAT scores of SWLDs. The findings of our study, which suggest a positive correlation between E-CTE participation and high school outcomes essential for college enrollment, are worth evaluating further to better understand the reasons for this relationship. Clarifying the existing situation would help practitioners improve the content and applications of E-CTE courses and create ways to support access to these courses for SWLDs. This would also aid in highlighting how E-CTE may help SWLDs make decisions about future postsecondary opportunities. In doing so, schools may ultimately help smooth the transition from high school to postsecondary education to career in STEM fields for this population of traditionally underrepresented students.

Beyond our immediate research, the findings of our work have implications for the instruction of SWLDs more generally and inclusion in the classroom. Specifically, the link between recommended accommodations for this population of students and the design of

CTE courses, in general, is closely aligned with the broader universal design of learning principles emphasizing differentiated instruction, cooperative learning, and reciprocal learning [27,35,36]. Through opportunities to participate in such pedagogical approaches, SWLDs may develop key skills helping to ease the transition to postsecondary settings. Broadly speaking, many of these pedagogical principles incorporated into CTE coursework by design could also benefit SWLDs across other fields of education as well.

4.2. Limitations and Future Research

Though we attempted to account for a wide range of factors in our analyses, a handful of limitations remain worth noting. One limitation is that this study relied on a secondary dataset; therefore, our analyses were limited to the variables provided. Because of this limitation, we cannot identify aspects of exactly what occurs in these E-CTE classes. To build on our current findings, it would be beneficial to find out precisely what is taught in class or how it is taught. Development of the three potential mechanisms—reinforcement of academic skills, new skill development, and relevance and engagement—through E-CTE course-taking is likely related to the quality of the courses and the applications of course material in the classrooms. Changes in CTE policy under *Perkins IV* and *V* reauthorizations in 2006 and 2018 identified the necessity to increase the participation of students from special populations in these courses. They carefully designed them to increase rigor and relevance. Future research could examine the content of these courses and determine whether they fulfill these objectives and how well the instructors teach math and science concepts through practical application. Additional work could employ a mixed-methods approach to understand better exactly how E-CTE courses may benefit students in their decisions in high school and as they follow the pathway beyond. This understanding would likely provide broader perspectives for improving E-CTE course content and application.

A second limitation may be the age of this data. This dataset follows a cohort of students who entered the 9th grade in 2009 through high school and into postsecondary education and early career. Though the students in the dataset graduated high school nearly a decade ago, HSLS is the most recent nationally representative dataset in existence that includes secondary and postsecondary student outcomes, making it a useful tool for analysis. However, a more recent dataset may be more effective when considering the changes in education until today to get a broader and up-to-date picture of student outcomes. Future work may look to pursue similar research questions using state administrative data that includes multiple cohorts of students up to the present day. Despite these considerations, conclusions based on these data remain informative and remarkable in helping to broaden the perspective on the high school course-taking, college applications, and stem-related major declarations behaviors of students from various groups. Considering the most recent reauthorization of the *Perkins Act* in 2018, which underscores the need to increase the participation of special and underrepresented student populations in the E-CTE courses and create a stronger link for them from high school to college, there is reason to believe that more recent work data show even stronger relationships.

A final limitation relates to the fact that students choose to participate in E-CTE courses. In other words, some key unobservable factors may lead to students enrolling in E-CTE, implying potentially important differences between those who enroll and those who do not. Regarding these individualistic perspectives, subject to qualitative measurements, it is impossible to construct a broader frame, including conclusions about the motivations and reasons behind student decisions. Two avenues of research spring from this limitation. Future research could benefit from qualitative methods to evaluate and understand the motives students have to enroll in E-CTE courses in high school and how these courses may ultimately influence outcomes. A second opportunity would focus on identifying an E-CTE program that uses a lottery system to grant admission and tracking students who enroll and those who do not, thus accounting for potential differences in motivation to pursue E-CTE. Such avenues of research would add a great deal of understanding to the CTE literature.

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