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RESEARCH ARTICLE

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Exploring the role of high school engineering courses in promoting science attitudes for students with learning disabilities

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Abstract

Demand for engineering-interested and proficient high school graduates continues to grow across the nation. However, there remains a severe gap in college participation and employment in engineering fields for students with learning disabilities (SWLDs). One potential way to encourage SWLDs to consider engineering as a profession and promote the development of key science attitudes may be through engineering and technology career and technical education (E-CTE) coursework. In this study, we address the following research questions: Do SWLDs take E-CTE courses in the early years of high school at different rates compared to students without learning disabilities? What is the relationship between early E-CTE coursetaking and science attitudes (self-efficacy, utility, identity), and does this differ for students with and without learning disabilities? How do specific engineering career expectations change with respect to enrollment in early E-CTE coursework, and do these differ for students with and without learning disabilities? We utilize the High School Longitudinal Study of 2009 (HSLS) to respond to the research questions through moderation models and a student fixed effects methodology. Ultimately, we found no evidence of SWLD underrepresentation in E-CTE in high school. However, SWLDs were expected to benefit more than the general population from E-CTE participation with respect to higher levels of science self-efficacy and science identity. Implications from these findings include how to encourage persistence along the engineering pathway, the growth of career pathway policies at the state level, and how to incorporate E-CTE practices in academic courses.

KEYWORDS

career and technical education, career expectations, engineering, science attitudes, students with learning disabilities

1 | INTRODUCTION

Demand for engineering occupations is predicted to increase rapidly over the next decade, with some engineering disciplines seeing up to a 23% increase (Bureau of Labor Statistics, 2016). Increasing demand in these fields necessitates a more concerted effort to grow student enrollment in engineering-related areas in secondary and higher education. Without meeting these labor market demands, the United States may not be able to keep up in the global economy (Goan et al., 2006). Yet, in contrast to increases in labor market demand, there has been a recent decline in the number of students enrolling in science, technology, engineering, and mathematics (STEM) fields in higher education (National Science Board, 2010). As such, the lack of students interested in engineering-related occupations is a concern for policymakers and educators, given the growth of these fields (Xue & Larson, 2015).

In addition to the growing need for trained engineers in industry, individuals who pursue engineering are also likely to benefit from a lucrative career. They tend to have substantially higher median wages than other occupations in the country (Bureau of Labor Statistics, 2016). Recent work by the National Association of Colleges and Employers (2019) suggested that engineering disciplines will employ the highest-paid bachelor's degree graduates of recent cohorts. More so, regardless of whether they end up working in engineering or other STEM disciplines, individuals with STEM backgrounds earn more and have more stable careers in the long term, further highlighting the benefits of gaining knowledge in STEM fields (Langdon et al., 2011).

Given the high national demand for and lucrative nature of engineering careers, policymakers and practitioners have sought ways to increase access to and participation in engineering along the educational pathway—that is, from high school to college and eventually career. Recent attention in this regard has focused on career and technical education (CTE) coursework, with engineering and technology career and technical education (E-CTE) coursework filling a critical STEM education need. STEM-related CTE pathways have been of particular focus given the existing research that suggests students who engage in and do well in STEM-related courses in high school have a better chance of succeeding in college and future careers (Maltese & Tai, 2011; Plasman et al., 2017; Sass, 2015). While this may be true, there is a dramatic mismatch between demand for engineers and individuals pursuing these fields in post-secondary institutions. Part of this reason certainly resides in the fact that many subpopulations of students are grossly underrepresented at all points along educational pathway in engineering (National Science Foundation, 2019). One group in particular, students with learning disabilities (SWLDs), are historically underrepresented in high school courses across numerous areas of STEM, despite evidence as to their capability for success in these areas if they are provided appropriate coursework and accommodations (Dexter et al., 2011; Plasman & Gottfried, 2018; Therrien et al., 2011). This underrepresentation in high school coursework translates to further gaps in participation along the pathway into college and career (Moon et al., 2012).

Learning disability is a very broad description for numerous different specific types of disability. Typically, students are diagnosed at a young age, with a majority receiving a learning disability diagnosis prior to entering high school (Arrhenius et al., 2021; Boat & Wu, 2015). The most common include dyslexia (issues with language processing), dysgraphia (issues in converting thoughts into writing), and dyscalculia (issues with mathematical calculations), which can have negative impacts on many of the skills needed to succeed in STEM fields (National Institute for Learning Development, n.d.). In particular, STEM education as delivered in traditional academic STEM courses is inaccessible to SWLD as instruction is typically not delivered via pedagogical approaches that most align with the needs of SWLDs (Moon et al., 2012; Plasman et al., 2021).

To date, there is little work exploring the potential benefits of E-CTE coursework for SWLDs, particularly with respect to factors influencing persistence in engineering and engineering-related fields. In this study, we address this gap by exploring how participation in E-CTE coursework may link to improvements in science attitudes and engineering interest for SWLDs. While E-CTE is a single career cluster as described in more detail below, it is important to note that this cluster encompasses engineering CTE courses and technology CTE courses. For the purposes of this study, we separate E-CTE into these two categories to obtain a more nuanced understanding of these courses. We refer to these two categories collectively as E-CTE throughout. In this study, we ask the following research questions:

> Research Question 1: Do SWLDs take E-CTE courses in the early years of high school at different rates compared to students without learning disabilities?
>
> Research Question 2: What is the relationship between early E-CTE coursetaking and science attitudes (self-efficacy, utility, identity)?
> (a) Does this relationship differ for students with and without learning disabilities?
>
> Research Question 3: How do specific engineering career expectations change with respect to enrollment in early E-CTE coursework?
> (a) Does this relationship differ for students with and without learning disabilities?

First, we look to examine the predictors of participation in E-CTE. Specifically, we are interested in exploring whether SWLDs are underrepresented in this field of study. With our second research question, we get into the heart of our study. Here, we make direct comparisons between students with and without learning disabilities and how E-CTE may link to the development of science attitudes differently for these two groups. This will help us understand how E-CTE may close some of the gaps in engineering participation for SWLDs. Finally, our third research question asks whether E-CTE may encourage interest in pursuing engineering as a career. We approach this question by examining changes in expectations for engineering-related occupations later in life. Knowing how these relationships differ by student learning disability status will help refine and develop programming and policy to better meet the needs of individual students as well as the broader labor market.

2 | WHAT IS E-CTE?

Gottfried et al. (2014) established a taxonomy of STEM coursework that focuses on two branches—general STEM and STEM-CTE. General STEM courses tend to be abstract in nature and often focus on text-based instruction. This branch includes courses typically associated with STEM, such as algebra, biology, chemistry, and calculus. STEM-CTE coursework, meanwhile, is specifically designed to engage students in real-world projects that strengthen their understanding of STEM subjects in general (Plasman & Gottfried, 2018). In addition to falling under the STEM umbrella, STEM-CTE coursework lies within the broader CTE framework, which consists of 16 career clusters. STEM-CTE typically focuses on the two clusters that are most closely associated with general STEM—information technology and engineering technology. E-CTE includes courses in engineering or engineering-related technologies such as surveying, ocean engineering, and electromechanical technology.

This direct connection between STEM-CTE and general STEM is made explicit in the Carl D. Perkins Strengthening Career and Technical Education Act of 2006—the fourth iteration of the Perkins legislation, which was most recently reauthorized in 2018 (Plasman et al., 2020). The full suite of Perkins legislation outlines funding and priority focal areas for CTE as a whole. The two most recent iterations, Perkins IV in 2006 and Perkins V in 2018, have placed a strong emphasis on integrating STEM knowledge with technical skills (Advance CTE, 2018). Specifically, as discussed in Perkins IV and continuing in Perkins V, E-CTE courses are structured to provide "competency-based applied learning that contributes to the academic knowledge, higher-order reasoning and problem-solving skills, technical skills and occupation-specific skills" (Carl, 2006; Carl D. Perkins Career and Technical Education Act, p. 4).

Ultimately, the Perkins Act aims to accord academic coursework in high school with applied career-related skills. Besides focusing on integrating academic learning with applied learning, Perkins V has included science in the accountability metrics for academic performance. Moreover, the 2006 and 2018 Perkins reauthorizations present two goals: equalizing CTE access for all students, including SWLDs, and increasing enrollments in STEM-CTE courses through this CTE curriculum (Advance CTE, 2018). These two recent iterations of the Perkins Act are significant because they point out the necessity for high school CTE courses to support students gaining academic and technical skills significant for their post-secondary achievements like high-demand careers, employment in high-skill, and high-wage, whether with or without a college education (Plasman et al., 2021).

As with academic STEM courses, E-CTE courses are meant to convey quantitative notions, problem-solving skills, and logical reasoning in well-arranged, rigorous classroom environments. But unlike academic STEM courses, STEM-CTE courses emphasize applying academic math and science concepts directly to practical job experiences by incorporating these quantitative reasoning, logic, and problem-solving skills into hands-on, experiential learning opportunities (Bradby & Hudson, 2007; Brand et al., 2013).

Indeed, the boundaries between engineering, science, math and technology are often quite blurred. A framework for science education by the National Research Council (2012) outlined seven core concepts that are central to both science and engineering education. These concepts include patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change. Though science tends to emphasize the search for understanding the natural world and engineering focuses more on applications, the relationships are evident, and the potential for E-CTE to play a key role in science and broader STEM knowledge and understanding is clear.

The core components of E-CTE courses—quantitative reasoning, logical reasoning, problem-solving—also align with the Next Generation Science Standards (NGSS) as designed in 2013. The NGSS portray performance expectations that demand all students have a profound understanding of a smaller number of disciplinary core ideas, can demonstrate that knowledge through scientific and engineering practices, and connect concepts of various disciplines (Pruitt, 2014). With the growing emphasis on competencies related to scientific research, the NGSS framework encourages the development of students' academic knowledge and skills through scientific and engineering practices (Pruitt, 2014).

E-CTE plays a key role in this process and in the NGSS more specifically. For example, "the NGSS represent a commitment to integrate engineering design into the structure of science education…. There are both practical and inspirational reasons for including engineering design as an essential element of science education" (Next Generation Science Standards, 2013). The goals of the NGSS to incorporate engineering design principles in combination with the focus in the Perkins Act to link technical skill acquisition to the understanding of complex STEM knowledge represent a concerted national effort to ensure students are equipped and prepared to succeed in STEM fields upon entering postsecondary education and the workforce.

2.1 | E-CTE course taking for SWLDs

The abstract nature of academic STEM coursework can be particularly daunting for SWLDs who may experience difficulties with reading, mathematics, and writing concepts (Jenson et al., 2011; Moon et al., 2012). This is could be due to the misalignment between practiced instructional strategies and those that may be most effective for SWLDs (Brigham et al., 2011). Importantly, many of the suggested accommodations for SWLDs—use of multiple senses, hands-on and lab experiences, and numerous demonstrations by the instructor—happen to align with the instructional methods of many E-CTE courses (Fraser & Maguvhe, 2008; McCarthy, 2005; Scruggs & Mastropieri, 2007). As such, this connection between the abstract and the practical through courses such as those in the E-CTE category may be particularly beneficial for SWLDs (Thurlow et al., 2002).

There is a body of research evidence identifying the benefits of CTE broadly for students with disabilities. For example, SWLDs who participated in career-focused courses in high school were more likely to earn industry-recognized credentials (Dougherty et al., 2018). Theobald et al. (2019) also found that SWLDs who participated in high school CTE were more likely to find employment after high school graduation. There is also a small but growing body of literature on the benefits of STEM-CTE for SWLDs. Shifrer and Callahan (2010) found evidence that SWLDs who participated in STEM-CTE coursework early in high school were more likely to complete advanced science coursework by the time they graduated from high school. Plasman and Gottfried (2018) found evidence that SWLDs who participated in high school STEM-CTE coursework were more likely to graduate high school on time, have higher mathematics achievement, and were more likely to enroll in college. Importantly, many of these outcomes for SWLDs represent benefits above and beyond those experienced by general education students, providing evidence that such courses may actually help close some of the gaps between SWLDs and general education students. However, there is a practically non-existent literature base on the benefits specifically focusing on E-CTE participation for SWLDs.

Two frameworks—Universal Design for Learning (UDL) and the Concrete-Representational-Abstract graduate sequence of instruction (CRA)—are particularly relevant in understanding how E-CTE may be particularly well-suited for SWLDs (Hwang & Taylor, 2016; UDL-IRN, 2011). UDL has a long relationship with education of individuals with disabilities and is prominently featured in education policies dating back to 1998 (OCALI, n.d.; Jimenez et al., 2007). Basham and Marino (2013) suggest that the foundations of STEM education lie in engineering and that UDL provides a particularly valuable set of core elements that align with needs of SWLDs. Specifically, UDL suggests that instruction include clear goals, intentional planning to account for heterogeneous learner ability, flexibility with respect to teaching methods and course materials, and staying up to date with monitoring student progress (UDL-IRN, 2011). Teaching techniques related to differentiated instruction, cooperative learning, reciprocal learning, thematic teaching, and community-based instruction are each central components to E-CTE that are also represented within the UDL framework (Dougherty et al., 2018; Jimenez et al., 2007).

CRA, likewise, provides important lessons that are applicable to the instruction of SWLDs in STEM education (Hinton & Flores, 2019; Basham & Marino, 2013; Peltier & Vannest, 2018). The basic tenets of CRA suggest that abstract and theoretical conceptions should be translated into concrete and practical applications to allow students the opportunity to physically visualize these concepts (Basham & Marino, 2013). The framework focuses on three phases of understanding that progressively allow students to connect the practical to the abstract, which may be particularly useful for SWLDs who often have difficulties with abstract thinking (Allsopp et al., 2007). As discussed by Agrawal and Morin (2016) in describing the effectiveness of CRA for SWLDs, the first phase focuses on the use of hands-on learning activities to make abstract concepts concrete. The second phase makes use of visual representations instead of physical manipulatives. The final phase encourages students to approach problem solving without the use of physical or visual representations. As with UDL, these principles of CRA are core components related to learning in E-CTE courses. While learning through practical and experiential learning experiences is beneficial for all students, there is strong theoretical and empirical evidence that SWLDs may particularly benefit from these opportunities as a way to better engage with the material and make connections between the practical and the conceptual (Brigham et al., 2011; Jenson et al., 2011). As such, E-CTE represents a means to support these students to more profoundly incorporate the key concepts of science and engineering (Fraser & Maguvhe, 2008; Plasman et al., 2022; Scruggs et al., 1993; Scruggs & Mastropieri, 2007; Steele, 2008).

2.2 | Early high school coursetaking

It is worth noting that the timing of these classes is also likely to matter (Gottfried & Plasman, 2018). Participating in STEM-CTE coursework early in high school is likely to set students up for success along the STEM pathway (Adelman, 2006; Schargel & Smink, 2001; Schneider et al., 1997; Shifrer & Callahan, 2010). By introducing courses that are designed specifically to engage students and to emphasize the relevance of course material early in high school, students may be more likely to develop an interest in the field which ultimately assists to better support engagement with high school coursework in general (Reiser, 2004).

2.3 | STEM capital, E-CTE, and science attitudes

Science capital, or STEM capital more broadly, represents a conceptual framework that helps explain and understand how individuals succeed in and choose to persist in science and other STEM fields (Archer et al., 2012). The original framework as first described by Archer et al. (2012) and more succinctly developed in later work by Archer et al. (2015) was developed as a means to describe an individual's science-related resources and tendencies, or lack thereof. The notion of STEM capital can be extrapolated from the science capital concept, as has been done in more recent literature (Cohen et al., 2021; Moote et al., 2020; Plasman et al., 2021). Under the STEM capital framework, multiple types of capital (e.g., cultural, social, and economic) are gathered together with a specific emphasis on STEM. As such, higher levels of STEM capital can be conceptualized as greater access to resources (e.g., finances, social networks and peer or mentor relationships, qualifications such as postsecondary credentials, and social prestige) in the cultural, social, and economic contexts (Archer et al., 2015). This mirrors the original notion of science capital but expands more broadly to STEM in general. Particularly salient to this study, the work by Moote et al. (2020) suggests that STEM capital, in addition to a strong relationship to science attitudes and aspirations, is quite strongly related to engineering attitudes and aspirations.

Central to the idea of STEM capital is the development of key STEM-related attitudes such as identity, self-efficacy, and utility. STEM identity refers to the extent to which individuals recognize themselves and are accepted by others as members of the STEM community or discipline (Cheryan et al., 2015; Tajfel, 1982). Individuals develop this identity through interactions with others in the field (Kim et al., 2018). These identity perceptions link to overall engagement and participation in the community (Wenger, 1998). If students do not see themselves as a "STEM person," they are less likely to persist in STEM-related fields (Carlone & Johnson, 2007). The extent to which students feel their identity is recognized and valued within the STEM community is likely to structure their engagement with science and affect their decisions on whether to pursue STEM-related education after high school (Archer & DeWitt, 2016; Calabrese Barton & Tan, 2010). For example, research suggests that adolescents with higher science-specific capital have more opportunities to develop a science identity, are eager to study science-related majors after high school, and are more likely to express positive approaches to science (Archer et al., 2012, 2015; DeWitt et al., 2016; Moote et al., 2020). E-CTE courses may provide a particularly useful avenue by which to develop attitudes related to STEM identity given how perceived identity can be heavily influenced by the perceptions and evaluations of those who are themselves members of the STEM community (Wenger, 1998). Specifically, by offering an opportunity to participate in STEM-focused experiential learning opportunities, which may be an ideal learning strategy for SWLDs (Agrawal & Morin, 2016; Basham & Marino, 2013), SWLDs may be able to highlight their abilities and skills in a different means than strictly through book learning.

Self-efficacy is the belief in one's own ability to succeed in a task or activity related to a specific subject (Bandura, 1977; Pajares, 1996; Schunk & DiBenedetto, 2016). Knowledge and skills are essential for academic success; however, one needs self-efficacy to access the skills and resources to learn (Bandura, 1977). Ultimately then, accomplishment and determination in STEM fields relate to one's STEM self-efficacy, and existing work indicates that participation in STEM-CTE coursework links to the development of STEM self-efficacy for the general population (Sublett & Plasman, 2017). E-CTE courses allows students to strengthen the academic knowledge they gain through traditional STEM courses. Spending extra time on math and science concepts through applied learning experiences can boost students' ability to succeed in all types of STEM courses (Stone et al., 2008), while simultaneously boosting STEM self-efficacy (Plasman et al., 2022).

The perceived usefulness (or utility) of a given subject for current or future pursuits is directly related to motivation to participate in that subject and completion of related tasks. As such, STEM utility represents a mechanism by which to understand future science pursuit and persistence given its malleable nature (Maltese & Tai, 2011; Simpkins et al., 2006). Empirically speaking, higher levels of utility in STEM fields link to improved likelihood of participation and success in advanced math and science coursework as well as higher probability of declaring a science major in postsecondary education (Lazowski & Hulleman, 2016; Simpkins et al., 2006; Updegraff et al., 1996). E-CTE courses are designed to establish a connection between academic knowledge and real-world applications to nurture students' STEM skills and knowledge, thereby encouraging students to directly observe the utility of a obtaining associated skills and helping to show how these skills may help students approach challenges they may encounter in STEM fields in college and career (Gottfried et al., 2014; National Research Council, 2011; Plasman et al., 2022).

For SWLDs who may not have access to the key STEM capital resources outside of school, opportunities such as E-CTE may serve as a way to help accumulate greater STEM capital (Archer et al., 2012). E-CTE courses may help SWLDs develop STEM identity through hands-on science lessons, encouraging relevance and engagement and open spaces to explore science concepts and ideas (Carlone & Johnson, 2007). Furthermore, providing educational environments enriched with applied learning methods is crucial to help SWLDs improve confidence in science and math, thus developing self-efficacy (Betz, 2004; Betz & Hackett, 1983; Lent et al., 1986; Taylor & Betz, 1983). 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 (Katehi et al., 2009). Furthermore, E-CTE coursework can make learning more meaningful since it is designed to support students in understanding the work of engineers by highlighting the link between engineering and science (Katehi et al., 2009; National Research Council, 2012). Particularly salient to our focus on SWLDs, existing evidence suggests that students traditionally underrepresented in science fields who participate in engineering learning opportunities, as suggested by the NGSS, are likely to see improvements in persistence in science (Barton et al., 2008). Additionally, the development of STEM capital and the associated attitudes appears to be particularly evident in engineering fields (Moote et al., 2020). Ultimately, E-CTE coursework likely supports SWLDs in the development of STEM capital, thereby helping them better learn and engage with STEM-related subjects, and ultimately succeed and persist along the STEM pipeline (Scruggs et al., 1993; Steele, 2010).

3 | METHOD

3.1 | Dataset overview

To respond to our research questions, we relied on nationally representative data from the High School Longitudinal Study of 2009 (HSLS). This dataset was collected by the National Center of Education Statistics (NCES) at the US Department of Education (see Ingels et al., 2015 for a full technical description of the dataset). The purpose of HSLS was to follow a cohort of students who began their freshman year of high school in 2009 as they progressed through high school and into college and eventually early career. The baseline surveys were collected in 2009 from students, parents, teachers, and administrators. Students were resurveyed in the spring of 2012 at which time a majority of students were expected to be juniors in high school. They were resurveyed again in the fall of 2013 and again in the spring of 2016 when most students in the sample were 3 years beyond high school. We relied on survey data from the baseline student, parent, and administrator wave, student first follow-up wave, and student third follow-up wave.

In addition to survey data, NCES also collected high school transcripts across the 2013–2014 years at which point a vast majority of students had successfully completed high school. These transcripts contained expansive detail regarding students' coursetaking histo- ries as well as grades and credits earned. Course credits were standardized across schools to Carnegie Units, such that one Carnegie Unit equates to 1 h of class time every day over the course of a school year. This standardization process ensured schools with different credit systems or scheduling designs (e.g., semesters, trimesters, quarters, block schedule) were comparable. Transcript data were checked to ensure accuracy such that students only received credit for courses they passed and that no duplicate records were included. Across the transcript data, NCES identified each unique course based on the school courses for the exchanged of data (SCED) codes as developed by the National Forum on Education Statistics (2014). By focusing on these codes, we were able to identify courses that fell into engineering or technology CTE, other CTE, and academic categories.

The full survey sample includes more than 23,000 students representing more than 900 schools across the country. However, inclusion in our analytic sample was contingent upon whether an individual had full transcript data, non-missing outcomes, and non-zero weights. This final analytic sample included 13,640 unique student observations, of which we identified 1040 as SWLDs. As per NCES guidelines, all reported sample sizes were rounded to the nearest ten. To ensure sample representativeness, we included student-level weights that identify membership in the baseline and first follow-up survey as well as inclusion of transcript data. To account for missing data, we relied on prior methodological work suggesting the imputation of 20 additional datasets (Graham et al., 2007). We imputed all variables to ensure the imputed values were as accurate as possible. However, throughout our analyses, we did rely on the observed values of our outcomes of interest given that some of the items used to create the attitude scales referred specifically to current STEM coursework, in which some students were not enrolled at the time. In such cases, these students who were not in an identified math or science class were excluded from the analyses. This recognized strategy—referred to as multiple imputation, then deletion—is appropriate in instances when imputing a key dependent variable may produce misleading interpretations, as would be the case here (Von Hippel, 2007).

3.2 | Students with learning disabilities

Our focus was on SWLDs, and therefore it was necessary to identify exactly how NCES defined this population within the dataset. In the baseline survey, NCES asked parents whether they had ever been told by a doctor or other professional that their child has a specific learning disability. As with prior research, we chose to identify learning disability status using this measure as opposed to relying on administrative reports of students who have individualized education plans (IEPs) identifying specific learning disability since the dataset had a large amount of missingness on the IEP item (Plasman et al., 2022).

3.3 | Outcomes

3.3.1 | Research question 1—E-CTE participation

Our initial outcomes focused on measures of participation in E-CTE coursework in 9th and 10th grades. We operationalized E-CTE participation as two unique binary indicator as to whether a student ever earned credit in either engineering or technology coursework in either grade. Note that these are two unique outcomes: one identifying engineering CTE participation and one identifying technology CTE participation.

3.3.2 | Research question 2—Science attitudes

We next turned to outcomes related to science attitudes. These attitudes constitute empirical measures of STEM capital. Specifically, we explored self-efficacy, utility, and identity in science. Each of these attitude scales was created as a composite variable by NCES. In creation of these variables, NCES validated the measures such that each met the appropriate level of reliability (Ingels et al., 2015). Self-efficacy includes items asking the following information: confident can do an excellent job on science tests; can understand science textbook; can master skills in science course; and can do an excellent job on science assignments. Utility compiles responses on items asking whether the student thinks their science course is useful everyday life, whether their science course will be useful for college, and whether they think their science course will be useful for future career. Finally, the identity composite includes the following items: views oneself as a science person; and others view you as a science person. Importantly, NCES collected identical items in each of the base year survey and the first follow-up survey, thus allowing us to directly compare change over time on these measures.

3.3.3 | Research question 3—Engineering career expectations

With respect to interest in engineering as a future profession, students were asked to respond to a question at each survey time point asking what job they expected to have at the age of 30 years. Each occupation was coded by NCES using the ONET scheme for job classification. Engineering occupations were all combined together and identified in this classification system as those with the 2-digit code of 17. Note this item is not a strict measure of any interest in engineering, but rather a proxy measure for interest as it indicates whether engineering is the expected career at age 30 years. As outcomes, we use student-identified expectations from the first follow-up survey when most students would have been juniors in high school and in 2016 when most students would have been 3 years out from high school. The question was asked in the same format in both waves.

3.4 | E-CTE high school coursetaking

As mentioned above, NCES coded every single course in which a student participated in high school using the SCED coding scheme. Using these SCED codes, we identified courses falling into either the engineering or technology categories. Examples of engineering CTE courses include Robotics, Principles of Engineering, and Engineering Analysis. Technology CTE includes such courses as Emerging Technologies, Wind Energy, and Drafting. Based on potential differential relationships between each of engineering and technology, we break these up into separate categories, though we refer to them collectively as E-CTE. We define coursetaking as the number of Carnegie units earned as opposed to number of courses taken as this allows us to better standardize the measurement of exposure to engineering and technology. Recall that we focus on units earned in either the first or second year of high school. As such, throughout this paper, our reference to engineering or technology coursetaking implies the number of units earned in those categories early in high school (i.e., the sum of units earned across the freshman and sophomore years). Across our full sample, students earned an average of 0.10 E-CTE credits (0.04 in engineering and 0.06 in technology). For our SWLD sample, students averaged 0.12 E-CTE credits (0.04 in engineering and 0.08 in technology).

3.5 | Control variables

We included a robust set of control variables in our models that align with those in prior studies on high school coursetaking (Bozick & Dalton, 2013; Dougherty, 2018; Plasman et al., 2021). Descriptive statistics for our identified covariates are presented in Table 1. Where possible, we include variables from the baseline survey, except for academic variables such as GPA, academic credits, and other CTE credits, which we sourced from the transcript data. We present statistics separately for our full sample, the SWLD sample, and the non-SWLD sample.

In the table, we break our control variables into three broad categories: sociodemographic variables, academic history and attitudes, and school-level variables. Both sociodemographic and academic variables are measured at the student level. The sociodemographic category includes variables such as gender, socioeconomic status (a continuous measure such that a higher value on the indicator implies higher socioeconomic status), race/ethnicity, family arrangement, and parent education. Academic history variables include 9th grade GPA, total number of core academic credits (i.e., math, science, English, and social studies) earned across the freshman and sophomore years, and a measure of whether a student participated in advanced math in 8th grade where advanced math is defined as algebra or higher. Academic attitudes reflect each of our attitude outcomes as identified above but measured during the base year. We also include a measure identifying postsecondary education expectations.

School variables include a range of demographic measures including percent of students as identified as English language learners, percent of students receiving free or reduced-price lunch, and percent of students identified as underrepresented minority. We used the National Science Foundation definition of underrepresented minority students that includes Black, Hispanic, and Native American students (National Science Foundation, 2019). We also included a binary indicator identifying whether a school was public or private as well as indicators of urbanicity. Finally, we included an NCES-created composite measure of school climate made up of 14 items indicating the extent of certain problems (e.g., bullying, drug use, vandalism, etc.) at the school as identified by the administrator who responded to

TABLE 1 Descriptive statistics.

	Mean	SD		Mean	SD
Learning disability status	0.07	(0.26)	Academic history and attitudes		
11th Grade STEM attitudes/interest (outcome)			Early engineering CTE credits	0.04	(0.22)
Science self-efficacy	0.02	(1.00)	Early technology CTE credits	0.06	(0.27)
Science utility	−0.01	(0.99)	Non-ET CTE credits	1.10	(1.19)
Science identity	0.03	(1.01)	9th grade GPA	2.71	(0.87)
Engineering Exp—11th grade	0.06	(0.24)	Early academic credits	11.54	(3.44)
Engineering Exp—postsec.	0.04	(0.19)	8th grade advanced math	0.38	(0.48)
Sociodemographic variables			Postsecondary expectations		
Female	0.50	(0.50)	High school or less	0.19	(0.40)
Socioeconomic status	−0.02	(0.72)	2-year college	0.08	(0.26)
Race/ethnicity			4-year college or more	0.74	(0.44)
Black	0.12	(0.33)	9th grade STEM attitudes/interest (baseline)		
Hispanic	0.22	(0.41)	Science self-efficacy	0.03	(0.98)
Asian	0.04	(0.19)	Science utility	0.01	(0.99)
Other race/ethnicity	0.09	(0.29)	Science identity	0.04	(0.99)
White	0.53	(0.50)	Engineering Exp—9th grade	0.05	(0.22)
Family arrangement			School variables		
Single parent household	0.31	(0.46)	Public high school	0.92	(0.26)
Both biological parents	0.54	(0.50)	Percent ELL	6.03	(10.03)
Other arrangement	0.14	(0.34)	Percent FRL	38.24	(24.94)
Highest parent education			Percent URM	39.27	(30.98)
High school or less	0.45	(0.50)	School climate	−0.55	(1.05)
Some college	0.17	(0.37)	Urban	0.31	(0.46)
Bachelor's or more	0.39	(0.49)	Rural	0.24	(0.42)
			Suburban	0.33	(0.47)
N					13,640

Note: All variables binary unless indicated here; 11th grade—math self-efficacy (-2.5 to 1.73); science self-efficacy (-2.47 to 1.64); math utility (-3.94 to 1.21); science utility (-3.31 to 1.41); math identity (-1.54 to 1.82); science identity (-1.74 to 1.86). SES (-1.75 to 2.28). Early engineering credits (0–4); early technology credits (0–3.5); early non-ET CTE credits (0–14); early academic credits (0–28.73). 9th grade GPA (0–4). 9th grade attitudes: math self-efficacy (-2.92 to 1.62); science self-efficacy (-2.91 to 1.83); math utility (-3.51 to 1. 31); science utility (-3.1 to 1.69); math identity (-1.73 to 1.76); science identity (−1.57 to 2.15). Percent EL, FRL, and URM (0–100). School climate (−4.22 to 1.97).

the survey. Higher scores on this measure indicated a more desirable climate, such that identified issues were less of a problem.

3.6 | Analytic approach

3.6.1 | Predictors of E-CTE

To respond to our first research question, which asked about the observable factors that related to participation in E-CTE coursework, we utilized a linear probability model to estimate predictors of participation in either engineering or technology CTE coursework early in high school. Linear probability models are particularly useful in exploring the relationship between selected independent variables and a binary dependent variable as the associated estimates can be interpreted as the percent change in the probability of observing an outcome (participation in E-CTE coursework in this case). Equation 1 below identifies our model of choice:

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

We ran this model separately to predict engineering or technology CTE coursetaking in 9th or 10th grades. In this equation, the term *CTE* represents whether student i in school j ever participated in engineering or technology in 9th or 10th grade. The term X_i is a vector containing all student variables including sociodemographics, academic history, and academic attitudes mentioned above. The vector represented by S_j contains all our school variables as identified above. Finally, the term ε_{ij} is a placeholder for the error term. We clustered our standard errors at the school level to account for the nesting of students within schools.

3.6.2 | E-CTE coursetaking and science attitudes

Our second research question asked whether participation in E-CTE coursework linked to differences in science attitudes for students with and without learning disabilities. Given these outcome variables fall on a continuous scale, we used ordinary least squares (OLS) regression to identify any potential relationship. The equation we used to estimate this relationship is identified as follows:

$$Y_{ij} = \beta_0 + \beta_1 ENG * SWLD_{ij} + \beta_2 TECH * SWLD_{ij} + \beta_3 X_i + \beta_4 S_j + \varepsilon_{ij}. \quad (2)$$

We ran this model separately for each outcome, Y, which included science self-efficacy, science utility, and science identity. The terms *ENG* and *TECH* identify the number of credits earned in either engineering or technology CTE courses in 9th or 10th grades. To estimate whether SWLDs benefit differently than non-SWLD students, we included a SWLD indicator as an interaction with our two variables of interest. As above, the X (student characteristics) and S (school characteristics) vectors contain our suite of control variables, and ε_{ij} represents the error term clustered at the school level. The main SWLD variable is incorporated within the student characteristics vector. Note that we also included indicators for the number of other CTE credits and academic credits earned within the vector X. For each outcome, we include the baseline measure of the same attitude. For example, in the instance where our outcome was science self-efficacy in the spring of 2012, we include science self-efficacy in the fall of 2009 as our key academic attitude control variable.

3.6.3 | E-CTE and engineering expectations

Our final research question asked whether there was a relationship between early E-CTE coursework and interest in engineering as defined by occupational expectations. Our model mirrored that in Equation (2). Given the binary nature of our outcomes, the results are interpreted using a linear probability model such that estimates represent an expected change in probability. We identified two outcomes related to engineering interest—expectations in the spring of 2012 and expectations in the spring of 2016. Recall that these expectations refer to which occupation a student expects to have at the age of 30 years. We include base year engineering expectations as a key control variable.

3.6.4 | Sensitivity test

Though we attempt to account for observable differences between students using our set of control variables, there remains the possibility that unobserved individual-level heterogeneity might have influenced participation in E-CTE as well as changes in attitudes or engineering interest. For example, from our data, we do not know what motivates students to take E-CTE courses. However, since we have repeated observations of the same students over multiple time periods, we can employ a student fixed effects model as follows:

$$Y_{ijt} = \beta_0 + \beta_1 ENG * SWLD_{ijt} + \beta_2 TECH * SWLD_{ijt} + \beta_3 X_{ijt} + \delta_i + \varepsilon_{ijt}. \quad (3)$$

In this model, the term δ_i represents student fixed effects—an indicator variable for each unique student in the dataset. The term X_{ijt} represents all time-varying variables from our set of control variables in our previous models, such as academic credits earned or other CTE credits earned. Note that any time invariant variables, such as gender or public-school indicator as well as the standalone SWLD indicator, were dropped from the model. The two time periods at which we observe students are at the beginning of high school, at which point all students had earned zero E-CTE credits, and again 2 years later when most students were juniors in high school. We were able to observe the number of engineering credits each student earned by this point in time—approximately halfway through their high school experiences. This change in credit earning over time allows us to utilize the student fixed effects model.

This specification is a powerful tool as it allows students to be compared across years in the dataset. In other words, we are able to compare a student to themselves in different years during which they may have accumulated engineering or technology credits. As such, student fixed effects models rely on within-student variation, in this case with respect to our key variable identifying either engineering or technology CTE participation, thereby allowing each student to essentially serve has his or her own counterfactual. Importantly, both observed and unobserved time-invariant characteristics remain fixed, thereby allowing us to isolate the relationships between engineering or technology coursework and students' attitudes and interests.

4 | RESULTS

4.1 | Research question 1—Predictors of E-CTE participation

Our first research question asked about the predictors of participation in engineering and technology CTE coursework early in high school. Table 2 presents the results of our analyses. Given our use of a linear probability model, the estimates can be interpreted as the percent change in the probability of participation. The most notable finding is that there is no differential in participation between students with and without learning disabilities. This is evidenced by the lack of statistical significance on the "LD" coefficient in the table, under both models. In addition, the size of the coefficient is, or approximates, zero in both models.

Our control variables suggest notable findings. Female students are significantly less likely to participate in both engineering (−0.04, $p < 0.001$) and technology (−0.06, $p < 0.001$) than their male counterparts. Eighth grade advanced math participation (0.02, $p < 0.05$) and science identity (0.01, $p < 0.05$) were significantly related to higher probability of participating in engineering coursework. In other words, students who viewed themselves, and who perceived that others viewed them, as science people were more likely to participate in engineering coursework. With respect to technology participation, Asian students (−0.04, $p < 0.001$) were less likely to participate in this type of coursework, while students with higher 9th grade GPAs were slightly more likely to participate in technology courses (0.01, $p < 0.05$). Regarding school characteristics, students in public high schools were significantly less likely to participate in both engineering (−0.04, $p < 0.001$) and technology (−0.05, $p < 0.001$) coursework as compared to students in private schools. Furthermore, students in schools with higher percentages of underrepresented minority students (−0.01, $p < 0.01$) were less likely to participate in technology coursework. Finally, with respect to technology coursework, higher school climate (−0.00, $p < 0.01$)—schools with fewer issues related to behavioral issues—was associated with a lower probability of participation, though at a very small magnitude.

4.2 | Research question 2—E-CTE and science attitudes

We next turn to our results identifying any potential associations between E-CTE coursework and science attitudes. Table 3 presents these findings. For clarity, we present only the main effects and interaction effects. Each column grouping (i.e., self-efficacy, utility, and identity) represents a unique regression. Note that all control variables identified in Table 1 are included in these analyses.

With respect to science self-efficacy, there are no significant main effects associated with SWLD status, engineering credits, or technology credits. However, for the SWLD population, each additional credit earned in engineering significantly relates to higher levels of science self-efficacy (0.27, $p < 0.01$) by junior year in high school. This significant interaction effect suggests that SWLDs who take engineering courses benefit with respect to increased STEM self-efficacy, and they actually benefit more than the general education population. Given each of our attitude variables was standardized to 0 with a standard deviation of 1, this finding implies that for each additional credit of engineering earned early in high school, SWLDs would expect to see more than a one-quarter increase in science self-efficacy.

Turning next to science utility, we see a much different pattern than we had observed for science self-efficacy. First, it is worth noting that SWLDs (−0.10, $p < 0.05$) have lower levels of

TABLE 2 Predicting engineering and technology CTE participation.

	Early engineering		Early technology	
	Coef.	Std. err.	Coef.	Std. err.
Learning disability status	0.00	(0.01)	0.01	(0.01)
Sociodemographic variables				
Female	−0.04***	(0.00)	−0.06***	(0.01)
Socioeconomic status	−0.01	(0.01)	0.01	(0.01)
Race/ethnicity				
Black	−0.01	(0.01)	−0.01	(0.01)
Hispanic	−0.01+	(0.01)	−0.01+	(0.01)
Asian	−0.00	(0.01)	−0.04***	(0.01)
Other race/ethnicity	−0.00	(0.01)	−0.01	(0.01)
Family arrangement				
Single parent household	0.00	(0.01)	−0.00	(0.01)
Both biological parents	0.01	(0.01)	−0.01	(0.01)
Highest parent education				
High school or less	−0.01	(0.01)	−0.01	(0.01)
Bachelor's or more	0.00	(0.01)	−0.02	(0.01)
Academic history and attitudes				
9th grade GPA	−0.00	(0.00)	0.01*	(0.01)
Academic credits	0.00	(0.00)	−0.00	(0.00)
8th grade advanced math	0.02*	(0.01)	0.01	(0.01)
Postsecondary expectations				
2-year college	0.01	(0.01)	−0.02	(0.01)
4-year college or more	−0.00	(0.01)	−0.02	(0.01)
STEM attitudes				
Science self-efficacy	0.00	(0.00)	0.00	(0.00)
Science utility	−0.00+	(0.00)	−0.01+	(0.00)
Science identity	0.01*	(0.00)	0.00	(0.00)
School variables				
Public high school	−0.04***	(0.01)	−0.05***	(0.02)
Percent ELL	−0.00+	(0.00)	0.00	(0.00)
Percent FRL	−0.00	(0.00)	0.00	(0.00)
Percent URM	−0.00	(0.00)	−0.01*	(0.01)
School climate	−0.00	(0.00)	−0.00**	(0.00)
Urban	0.00	(0.01)	−0.01	(0.01)
Rural	−0.01	(0.01)	−0.02	(0.01)
N	12,820		12,820	

Note: Standard errors in parentheses.
$^{+}p < 0.10$;
$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

TABLE 3 Science attitudes.

	Self-efficacy		Utility		Identity	
	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
Main effects						
SWLD	−0.05	(0.06)	−0.10*	(0.05)	−0.09*	(0.05)
Engineering credits	0.04	(0.06)	0.11*	(0.05)	0.09*	(0.04)
Technology credits	−0.08	(0.05)	−0.05	(0.05)	−0.01	(0.04)
Other CTE credits	−0.03*	(0.01)	−0.03*	(0.01)	−0.02	(0.01)
Academic credits	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
Interaction effects						
Engineering x SWLD	0.27**	(0.10)	−0.05	(0.13)	0.37*	(0.19)
Technology x SWLD	0.04	(0.10)	0.10	(0.10)	0.14	(0.10)
N	12,820		12,820		12,820	

Note: All models include full set of control variables; standard errors in parentheses.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

science utility by junior year in high school than their non-SWLD counterparts. There is also a significant main effect for engineering credits (0.11, $p < 0.05$), implying that for all students, each engineering credit is associated with one-tenth of a standard deviation perception of science utility. There are no significant interaction effects for either engineering or technology, meaning that SWLDs do not experience any different effect of E-CTE compared to those from the general population with respect to science utility.

Finally, in the instance of science identity, we find evidence of both significant main and interaction effects. We find that SWLDs (-0.09, $p < 0.05$) are expected to have lower feelings of science identity, while each additional engineering credit (0.09, $p < 0.05$) is associated with higher feelings of science identity. For the SWLD population, each additional credit of engineering CTE (0.37, $p < 0.05$) earned is associated with an additional increase in feelings of science identity by more than one-third of a standard deviation as evidenced by the significant interaction effect. In other words, SWLDs who take more engineering CTE credits are expected to have higher science identity than SWLDs who do not, and this group of students benefits above and beyond the general education population.

4.3 | Research question 3—E-CTE and engineering career expectations

Our final research question asked whether students who participated in E-CTE coursework saw higher levels of interest in pursuing engineering as an occupation. Table 4 presents our findings. Recall that for these estimates, we employed a linear probability model. As such, the coefficients can be interpreted as percent increases in the probability of expressing interest in an engineering occupation later in life. Focusing first on engineering expectations as expressed during high school, we find two significant main effects, such that both engineering (0.10, $p < 0.001$) and technology (0.05, $p < 0.01$) coursetaking each link to increased probabilities of expressing interest in engineering as a career later in life. However, the

TABLE 4 Engineering expectations.

	Exp.—11th grade		Exp.—postsecondary	
	Coef.	Std. err.	Coef.	Std. err.
Main effects				
SWLD	−0.01	(0.01)	−0.01*	(0.00)
Engineering credits	0.10***	(0.02)	0.06**	(0.02)
Technology credits	0.05**	(0.02)	0.06**	(0.02)
Other CTE credits	−0.01**	(0.00)	−0.00*	(0.00)
Academic credits	0.00	(0.00)	0.00	(0.00)
Interaction effects				
Engineering x SWLD	−0.09*	(0.04)	−0.03	(0.05)
Technology x SWLD	−0.02	(0.04)	−0.05	(0.03)
N	13,640		12,090	

Note: All models include full set of control variables; standard errors in parentheses.
$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

interaction term for SWLDs earning engineering credits (-0.09, $p < 0.05$) indicates that SWLDs who earn engineering credits do not benefit in the same way that the non-SWLD population might—at least with respect to early engineering expectations. Finally, the coefficient for other CTE coursetaking (-0.01, $p < 0.01$) implied a lower probability of identifying engineering as a potential future career.

Turning next to engineering expectations as expressed after high school, we again observe a number of significant main effects. First, SWLDs (-0.01, $p < 0.05$) are significantly less likely to identify expectations for an engineering occupation than non-SWLDs. However, both engineering (0.06, $p < 0.01$) and technology (0.06, $p < 0.01$) remain significantly associated with higher probabilities of identifying engineering as an expected occupation later in life. Again, other CTE coursework (-0.00, $p < 0.05$) linked to a lower probability of having engineering expectations. In this model, there were no significant interaction effects.

4.4 | Sensitivity test

4.4.1 | Science attitudes

Given the potential differences between students with respect to motivation to pursue and ability in E-CTE courses as well as any other observable or unobservable differences, we used a student fixed effects technique to provide a more robust estimate related to our relationships of interest. Table 5, panel A, presents the results of these analyses. Note that in these models, there is no SWLD main effect as this variable does not vary over time. However, the interaction between SWLD and engineering/technology credits does vary over time, allowing us to observe an interaction effect.

Turning first to science self-efficacy, we observed a negative main effect for technology credits earned (-0.14, $p < 0.05$), but a fairly large interaction effect for SWLDs earning engineering credits (0.59, $p < 0.001$). With respect to science utility, the only significant

TABLE 5 Student fixed effects.

	Self-efficacy		Utility		Identity	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
Panel A: Science attitudes						
Main effects						
Engineering credits	−0.02	(0.05)	0.13*	(0.06)	0.03	(0.06)
Technology credits	−0.14*	(0.06)	0.04	(0.06)	−0.00	(0.06)
Other CTE credits	0.00	(0.02)	−0.03	(0.01)	0.01	(0.01)
Academic credits	0.00	(0.00)	0.00	(0.01)	−0.00*	(0.00)
Interaction effects						
Engineering x SWLD	0.59***	(0.09	0.01	(0.13)	0.67*	(0.33)
Technology x SWLD	0.19	(0.13)	0.28	(0.18)	−0.03	(0.18)
N	25,640		25,640		25,640	

	Exp.—11th grade		Exp.—Postsecondary	
	Coef.	Std. Err.	Coef.	Std. Err.
Panel B: Engineering expectations				
Main effects				
Engineering credits	−0.03**	(0.01)	−0.11***	(0.01)
Technology credits	−0.01	(0.01)	−0.01	(0.01)
Other CTE credits	0.00	(0.00)	0.00	(0.00)
Academic credits	0.00***	(0.00)	−0.00**	(0.00)
Interaction effects				
Engineering x SWLD	0.04	(0.03)	0.12***	(0.03)
Technology x SWLD	0.01	(0.03)	−0.01	(0.03)
N	27,280		24,180	

Note: All models include full set of control variables; standard errors in parentheses.
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

coefficient was for the main engineering credits effect, such that for all students, each additional engineering credit was associated with an increase in science utility of 0.13 standard deviations as compared to freshman year. Finally, there were no practically significant main effects with respect to science identity, though there was a large interaction effect for SWLDs earning engineering credits such that each additional credit was associated with two-thirds of a standard deviation higher feelings of science identity compared to freshman year. These significant interaction effects for self-efficacy and identity are in alignment with our baseline estimates, though of substantially larger magnitude.

4.5 | Engineering career expectations

As with STEM attitudes, there were potential unobservable differences between students who may have influenced our estimation of engineering interest. Panel B in Table 5 presents our findings from these analyses. In considering the expectation for an engineering career as expressed during the junior year of high school, there was a negative, significant relationship associated with earning engineering credentials (−0.03, $p < 0.01$) for all students, indicating each engineering credit was associated with a 3% lower probability of expressing engineering expectations by junior year (compared to ninth grade expectations). For engineering expectations as expressed after high school, each engineering credit was associated with an 11% lower probability of expectation for an engineering career. However, there was also a significant interaction effect for SWLDs such that they had a higher probability of expecting an engineering career (0.12, $p < 0.001$).

5 | DISCUSSION

Finding ways to encourage participation in and persistence along the engineering pathway is essential in the mission to provide students with the knowledge and skills so they have the opportunity to pursue high wage careers and to meet the high demands of the engineering labor market. Encouraging participation and persistence for traditionally underrepresented students is a particularly important consideration. Though SWLDs may be underrepresented in the engineering workforce (Moon et al., 2012), the results of our paper indicate this underrepresentation gap in employment is not reflected in an underrepresentation in engineering coursework in high school. This is an important finding given the call under the two most recent Perking legislation reauthorizations to emphasize the inclusion of certain special populations (such as SWLDs) in rigorous and relevant STEM-focused career education. While SWLDs were not underrepresented in E-CTE courses, there were two groups worth mentioning who were: female students and Asian students. Female students were underrepresented in both engineering and technology courses, which aligns with findings that women in general are underrepresented in STEM fields, including engineering (Kahn & Ginther, 2017). With respect to Asian students, we observed an underrepresentation only in technology coursework, which may reflect findings by Moote et al. (2020) that STEM capital is not as strongly related to technology fields as it is to science, engineering, and mathematics.

Furthermore, this finding that SWLDs in the HSLS dataset were not underrepresented in high school E-CTE courses is particularly relevant given our findings that participation in these courses links to higher science attitudes. Though all students appear to benefit to some extent from participation in E-CTE coursework, SWLDs appear to benefit to an even greater extent. In other words, SWLDs who participated in engineering coursework were closing the gap with non-SWLDs with respect to feelings of science self-efficacy and science identity in particular.

One major contribution of our study, though, is a null finding in some respects. That is, we did not observe this closing of gaps between students with and without learning disabilities when it came to science utility. That is to say, SWLDs did experience a unique benefit on science utility, but it was the same benefit as general education students who participated in engineering coursework. In other words, our study has highlighted that all students who took engineering coursework exhibited higher levels of STEM utility, but if we are looking for E-CTE courses to close gaps between students with and without disabilities when it comes to utility, this would not be a solution. Additionally, SWLDs were expected to have lower initial levels of STEM utility, and one earned credit in engineering approximately offsets this initial discrepancy.

Developing each of these attitudes is an important step in promoting persistence along the engineering pathway as each is empirically linked to educational persistence and attainment

(Betz, 2004; Carlone & Johnson, 2007; Lazowski & Hulleman, 2016). It is worth pointing out that these benefits appear to be limited to engineering coursework as there were no significant differences for technology coursework.

With respect to engineering expectations, it is difficult to state with confidence that E-CTE coursework is helpful in encouraging students to identify engineering career expectations. Based on our baseline models, it appears both engineering and technology courses relate to higher probability of engineering career expectations for the general population at both the high school and postsecondary timepoints, but under our more rigorous student fixed effects models, it appears engineering credits may actually have a negative relationship with engineering career expectations. Furthermore, under our baseline models, SWLDs appeared to be even less likely to identify engineering career expectations during high school when taking engineering courses. However, under our student fixed effects models, SWLDs appeared to benefit in this regard, but only with respect to engineering career expectations expressed at the postsecondary timepoint. As with each of the science attitudes, personal career interests have empirical associations with decisions to persist along a pathway (Renninger, 2000), further highlighting the importance of helping students develop these expectations and interest.

5.1 | Implications for policy

Our work presents a number of important implications for both policy as well as teaching and learning. First, at the policy level, our work shows that participation by SWLDs in rigorous and relevant engineering-focused career education appears to be equal among students with and without learning disabilities, at least at the high school level. However, given the participation gaps that are evident in college and career in engineering fields for SWLDs, it is necessary to consider how to smooth the transitions from high school to college and college to career. Though there are clear links between CTE-specific legislation (i.e., Perkins) and guidance for science instruction (i.e., NGSS), future policy considerations should take this into account and work to develop articulated pathways with stackable credentials in order to encourage persistence for traditionally underrepresented groups. Regardless, given our findings that participation in E-CTE coursework links with improvements in key science attitudes, particularly for SWLDs, continuing to encourage participation in these courses should remain a policy priority.

Second, E-CTE appears to be particularly helpful in promoting science self-efficacy and science identity for SWLDs themselves. As mentioned above, these two attitudes play key roles in science-related achievement and persistence (Archer & DeWitt, 2015; Carlone & Johnson, 2007; Wenger, 1998). Additionally, self-efficacy is an important measure that is a precursor to many other positive outcomes related to achievement and persistence in STEM (Betz, 2004; Honicke & Broadbent, 2016; Lewis, 2003), and it should be viewed as an important outcome on its own. It is becoming more and more common for states and districts to implement policies requiring completion of a career pathway as a prerequisite for high school graduation, and this pathway is often STEM related. As states and districts help schools broaden their offerings of courses, students will have increased access to STEM courses, such as E-CTE. The hope is that this would broaden participation as well. If such state policies ultimately increase the number of students in engineering coursework, this may be one way to further help improve the overall engineering pathway as well as general STEM persistence.

Interestingly, there was no isolated benefit of E-CTE participation for SWLDs with respect to development of science utility. This could be one reason for later gaps in college-related engineering studies and engineering as a career for SWLDs. If students do not see the usefulness of science in their later steps in college and career, they are less likely to persist in science and STEM in general (Lazowski & Hulleman, 2016). Though the Perkins legislation highlights the need to ensure coursework is relevant, there appears to be room for growth in this area, particularly for SWLDs.

5.2 | Implications for teaching and learning

A final implication relates to practice of teaching and learning. By the nature of the way that they are designed, E-CTE courses utilize many of the teaching and learning accommodations that support SWLD learning and success (Fraser & Maguvhe, 2008), which might include UDL, multisensory learning, assistive technology, scaffolded instruction, and personalized learning. While we cannot say for certain which of these approaches are utilized in E-CTE courses (and would be ideal for future qualitative classroom-level research), the tenets of the construction of career and technical education certainly open opportunities for these pedagogical practices to be used. Being exposed to many of these pedagogical approaches, SWLDs have developed more opportunities to succeed in STEM, and, in the context of our study, being in E-CTE classes helps to develop science self-efficacy. This in turn may lead to greater identification as a science person. Continuing to embrace these practices in E-CTE courses, and possibly implementing similar strategies across other fields, may further help SWLDs develop attitudes that promote success and persistence in engineering and other STEM fields.

Overall, then, this study helps to underscore that E-CTE courses themselves may help to promote science attitudes. But what is certainly more complex is pinpointing what in particular about teaching might be related to imparting feelings of science self-efficacy for instance. In other words, while we can identify links between E-CTE classes and science attitudes, the reality is that teaching engineering to SWLDs is a complex and multifaceted issue that requires further attention from educators, policymakers, and researchers. Thus, an implication for practice would be to best identify what it is about the practice of teaching E-CTE that help SWLDs learn, build skills, and develop science attitudes in STEM-CTE classrooms. What moves the needle may be pedagogical, such as providing access to assistive technology or using multisensory teaching methods to support learning and science identity. On the other hand, what moves the needle may be more developmental, such as providing additional non-pedagogical supports like guidance and counseling. However, the prescribed instructional techniques in E-CTE courses—hands-on experiences, applied learning opportunities, experiential learning (Brand et al., 2013)—align very well with the core tenets of both UDL and CRA, and future work could consider what it is about E-CTE specifically that is well-suited SWLDs and their science learning.

Moving forward, there is also a need for more research on effective teaching strategies and accommodations for SWLDs in engineering education. This research should involve collaboration between teachers, disability specialists, and engineering professionals to ensure that the needs of these students are fully understood and addressed. That is to say, this study has identified that E-CTE courses matter for SWLD's development in feelings around science. We underscore that this has hypothesized implications for teaching and learning. To better unpack these implications, the research field can support SWLDs by best understanding what is it about E-CTE teaching that equips SWLDs with the tools and resources they need to succeed, ultimately creating a more diverse and representative engineering student body and workforce.

5.3 | Limitations and future research

There are a few potential limitations to keep in mind with respect to this study, though each limitation could be used to further the field of research. First, measuring attitudes is always a difficult proposition. We did not create the attitude measures ourselves, and we chose to rely on the component variables created by NCES. In so doing, we may be limited in a full understanding of each of the identified attitudes. However, given the purposes of our work, we believe the measures to be viable representations of the true aspects we are hoping to measure. Future psychometric work could look to replicate these findings with more comprehensive measures of each of the identified attitudes. This could be done through the dissemination of surveys or direct assessments given to SWLD, possibly on a smaller scale in a single district. In this regard, when linked to students' coursework, it would be possible to corroborate the findings of our national study with additional attitudinal measures in a district study.

A second limitation is that we were constrained by the timing of the data collection waves in two ways. First, we ideally would have liked information with respect to science attitudes to be collected at more than two time periods. This would have provided a much more complete picture as to changes in attitudes over time and allow for a deeper understanding as to how E-CTE related to these changes. As with above, primary data collection efforts that follow a cohort of students over time could be used to replicate our findings here. This would be particularly effective if it were used in conjunction with a program of study that used a random lottery for admission decisions, thereby allowing us to account for other potential unobservable biases. A second timing issue has to do with the age of the data. However, this is the most recent nationally representative dataset that includes information related both to coursetaking behaviors as well as science attitudes and career expectations. Though state administrative datasets may include more recent data, they would not include the attitude and expectation information. Despite this potential limitation, the findings remain relevant today given the continued growth of STEM-related careers and the expanding focus on CTE in general.

Finally, despite our positive findings linking E-CTE to higher science attitudes, it is worth pointing out that the work to ensure equitable access to and participation in engineering careers for SWLDs is not finished—namely because our work calls for further explanation of pedagogy, as described in the previous section. Though we can speculate as to the why these courses are helpful for SWLDs, the field at present does not have an in-depth understanding into how E-CTE courses are being taught. Our work was an exploratory study to examine trends, and our results hence lead to the need for further explanatory qualitative work to explore classroom practices. Through interviews with students and teachers as well as classroom observations, it would be possible to obtain a much broader perspective as to why the teaching of E-CTE courses may help SWLDs learn, persist, and succeed along the engineering pathway. Furthermore, such a study would also allow for richer insight into what adjustments could be made to strengthen this pathway. Combined with the results of our present study, such a qualitative study would greatly add to the understanding of the teaching of E-CTE courses and the processes and mechanisms by which they help students as well as how to improve the connections between course participation and expectations for engineering careers. In other words, though we are optimistic about the observed benefits of E-CTE participation for SWLDs, there is still room for further insights.

Despite these possible limitations, our study provides strong evidence as to the potential for E-CTE courses to help SWLDs develop the science attitudes necessary to persist along the engineering pathway from high school to college to career. Given the malleable nature of coursetaking, this is indeed an important finding as these courses can be used as a means to help students with regards to the development of strong science attitudes. This may particularly be the case for SWLDs who traditionally have not seen as much success in academic STEM courses. Ultimately, our work provides evidence that the funding provided through the Perkins legislation to support E-CTE, and CTE more generally, is having the desired effect in areas that extend beyond traditional achievement and employment outcomes.

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