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STEM-Focused Career Courses and College Pipeline for Students with Learning Disabilities

Jennifer A. Freeman[1], Michael A. Gottfried[1], and Jay Stratte Plasman[2]

Abstract

Recent educational policies in the United States have fostered the growth of science, technology, engineering, and mathematics (STEM) career-focused courses to support high school students' persistence into these fields in college and beyond. As one key example, federal legislation has embedded new types of "applied STEM" (AS) courses into the career and technical education curriculum (CTE), which can help students persist in STEM through high school and college. Yet, little is known about the link between AS-CTE coursetaking and college STEM persistence for students with learning disabilities (LDs). Using a nationally representative data set, we found no evidence that earning more units of AS-CTE in high school influenced college enrollment patterns or major selection in non-AS STEM fields for students with LDs. That said, students with LDs who earned more units of AS-CTE in high school were more likely to seriously consider and ultimately declare AS-related STEM majors in college.

Keywords

STEM, career and technical education, education policy, students with learning disabilities, secondary data analysis

[1]University of Pennsylvania, Philadelphia, USA
[2]The Ohio State University, Columbus, USA

Corresponding Author:
Jennifer A. Freeman, Graduate School of Education, University of Pennsylvania, 3700 Walnut Street, Philadelphia, PA 19104-6216, USA.
Email: jafree@upenn.edu

Participation in high school STEM coursework is instrumental in ensuring that students continue through the STEM pipeline—what is defined as high school to college and ultimately into career (Moon et al., 2012; National Science Foundation, 2015). Unfortunately, students with learning disabilities (LDs) are historically underrepresented in high school STEM courses and consequently throughout this pipeline, despite being highly capable of succeeding in STEM content areas when provided appropriate coursework and/or accommodations (Dexter et al., 2011; Therrien et al., 2011). For instance, students with LDs accrue fewer STEM courses in high school and graduate less college-ready in STEM areas than students without LDs, providing evidence of a leaky STEM pipeline at the first "node" (i.e., high school; Blackorby & Wagner, 1996; Shifrer et al., 2013). By not pursuing high school STEM courses, students with LDs are less likely to pursue STEM degrees in college (Lamb et al., 2004; Moon et al., 2012). More so, those who do take STEM courses in high school do not always end up persisting in the STEM pipeline beyond secondary education (Moon et al., 2012).

These disparities in high school STEM coursetaking are problematic given the well-established importance of high school STEM coursetaking on both high school success as well as college outcomes (e.g., Adelman, 2006; Brody & Benbow, 1990; Burkam et al., 1997; Federman, 2007; Joyner et al., 2002; Lee & Frank, 1990; Long et al., 2012; Riegle-Crumb, 2006; Schneider et al., 1997; Shifrer et al., 2013; Trusty, 2002; Wang, 2013; Wimberly & Noeth, 2005). Limited high school STEM coursetaking of students with LDs may be attributed to the multidimensional barriers these students face while accessing STEM education. Parents and teachers often times have misconceptions about the abilities of students with LDs to succeed in STEM coursework, consequently resulting in students being advised to take courses in other subjects (Alston & Hampton, 2000; Alston et al., 1998, 2002; National Science Foundation, 2002). Whether attributable to the "LD" label itself, which has been shown to inhibit students' access to advanced courses in the STEM curricula (Shifrer et al., 2013), or to teachers' ability to appropriately present STEM instruction that is sensitive to their needs (Rule et al., 2009), the lack of high school STEM coursetaking may largely influence the limited involvement of students with LDs in STEM fields in college and beyond (Eriksson et al., 2007).

In an attempt to attenuate the underrepresentation of students with LDs in STEM fields in college, determining ways to prepare students to enter the STEM pipeline *before* college has become a focus of educational policy. As one prominent example, there has been a policy focus on improving high school STEM coursetaking rates via recent reauthorizations of the federal legislation. Now in its fifth iteration (reauthorized in 2018), the Carl D.

Perkins Career and Technical Education Act represents a major policy push to maintain and further expand career and technical education (CTE) programming in order to link high school coursetaking to college pathways and career opportunities. More specifically, CTE courses in high school are designed to align applicable career-related skills with academically challenging coursework—this is not, vocational education in the traditional sense (Gottfried et al., 2014).

As it relates to this present study, the two most recent reauthorizations of the Perkins Act (2006 and 2018) call to not only boost access to the CTE curriculum for students with disabilities, but also call to increase STEM pursuits in particular. This has arisen through the expansion of CTE course offerings in what is known as "Applied STEM" (Gottfried et al., 2014) coursework—a strand embedded within the more general CTE curriculum (often called in the literature as: applied STEM CTE, or AS-CTE). AS-CTE courses focus on applying relevant STEM skills into two of the sixteen broad CTE career clusters: engineering technology and information technology (Bradby & Hudson, 2008). For a complete list of CTE career clusters, see Appendix 1. Courses within these two AS-CTE categories emphasize the application of math and science concepts to directly address real-world STEM problems by incorporating "hands on" quantitative reasoning, logic, and problem-solving skills (Gottfried et al., 2014).

To date, little empirical research has assessed how AS-CTE coursetaking in high school might strengthen the secondary-to-postsecondary STEM pipeline for students with LDs. Moreover, much of the existing literature has focused on AS-CTE coursetaking as it relates to high school outcomes. Yet knowing if AS-CTE courses also help to promote pursuits in STEM in college will be important for policy makers and educators for two reasons. First, the Perkins Act reauthorizations themselves have been developed in such a way to better link high school to college (and particularly for underrepresented groups, like students with disabilities). Yet, little work has asked whether this is so. Second, our study will help shed light on the importance of AS-CTE coursetaking in the future, as policymakers and practitioners consider new or revised educational policies to support the secondary-to-postsecondary link for students with LDs.

AS-CTE Coursetaking

STEM courses in the high school curriculum fall into two strands: academic and applied (Gottfried et al., 2014). Academic STEM courses—such as geometry and chemistry—are taught in a theoretical approach that stresses procedures, observation, identification, documentation, and computation

(Plasman & Gottfried, 2018). In contrast, AS-CTE courses emphasize the application of math and science concepts to real-world STEM tasks rather than through abstraction and content comprehension (Plasman & Gottfried, 2018). AS-CTE courses are intended to build upon material taught in academic STEM courses. Examples of courses include surveying and electrical engineering in the engineering technology cluster, and visual basic programming and data processing in the information technology cluster. Previous research has demonstrated a wide range of positive high school STEM outcomes associated with AS-CTE coursetaking in high school for the general student population, such as subsequent enrollment in advanced math and science courses, higher chances of high school completion, improved STEM self-efficacy, and improved overall achievement in high school (Lee & Burkam, 2003; Gottfried, 2015; Gottfried & Plasman, 2018; Sublett & Plasman, 2017).

Landscape for students with LDs. Students with LDs have historically struggled in academic STEM courses (Lamb et al., 2004; Moon et al., 2012; Powell et al., 2013). Playing a large part in this struggle is the fact that instructional practices in these courses tend to be in misalignment with the instructional practices identified as most effective for students with LDs (Brigham et al., 2011). In traditional academic STEM classes, knowledge relies heavily on text-based instruction and memorization, but students with LDs often face difficulties in literacy making these courses especially challenging (Parmar et al., 1994; Powell et al., 2013; Scruggs et al., 2013). Students with LDs, meanwhile, tend to learn better through the use of multiple senses, hands-on opportunities, and use of demonstrations by the instructor (Scruggs & Mastropieri, 1993; Steele, 2010). Given that language-based learning in academic courses may place students with LDs at a disadvantage, the applied instructional practices and accessibility of AS-CTE courses may be more effective in promoting STEM learning for this group of students (Maccini & Gagnon, 2000; Plank et al., 2008; Witzel, 2005).

By design, AS-CTE courses promote a hands-on, activity-based learning environment with connections to real-life applications of STEM curricula (Brand et al., 2013). This alignment between AS-CTE instructional practices and recommended accommodations for students with LDs may therefore serve as a means to better engage these students specifically with STEM material in order to ultimately encourage postsecondary interest in STEM fields (Kjaernsli & Lie, 2011; Milesi et al., 2017). This idea is borne out in research focused on students with LDs. Shifrer and Callahan (2010) found that students with LDs who took more units of AS-CTE coursework were more likely to enroll in advanced academic math and science courses.

Similarly, Plasman and Gottfried (2018) found that students with LDs who took AS-CTE courses in high school had higher math test scores and were less likely to drop out of high school.

As mentioned above, academic STEM coursework can be particularly difficult for students with LDs (Jenson et al., 2011). Building on the idea that AS-CTE coursework can promote engagement through more applied learning opportunities, students with LDs themselves have indicated a preference toward learning through more hands-on approaches (Jenson et al., 2011; Scruggs & Mastropieri, 1993). Further, students with LDs performed better when instruction focused on employing applied learning techniques (Brigham et al, 2011; Moon et al., 2012).

Closely related to engagement is the concept of relevance. Stone and Lewis (2012) identify the need for college and career coursework (i.e., CTE) to connect learning directly to postsecondary opportunities. Considering AS-CTE is specifically designed to make the connection with later STEM opportunities, this relationship between practical application and abstract concepts may be of particular benefit to students with LDs as they consider the pursuit of STEM studies in postsecondary education (Gottfried & Sublett, 2018).

As identified above, the benefits of AS-CTE coursetaking for students with LDs have been noted in terms of high school outcomes (Plasman & Gottfried, 2018; Dougherty et al., 2018; Shifrer & Callahan, 2010), but very little research has been conducted on the college outcomes associated with AS-CTE coursetaking. These studies provide some insight to the potential power of these courses for high school students with LDs, but more research is needed on whether AS-CTE coursetaking can help students with LDs persist in these fields in college.

Mechanisms. In an effort to explain why AS-CTE coursetaking in high school may influence college outcomes, we rely on three theorized mechanisms by which AS-CTE may benefit students: academic reinforcement, relevance and engagement, and skill formation (Gottfried et al., 2014; Plank et al., 2008). We believe that these three mechanisms may help describe the link between AS-CTE coursetaking and college major selection in STEM fields for students with LDs. First, because the AS-CTE high school curriculum complements rather than supplants material taught in traditional STEM courses, students taking AS-CTE courses have multiple opportunities to reinforce their previously-learned academic STEM knowledge (Bozick & Dalton, 2013; Shifrer & Callahan, 2010). When students have more time to dedicate to science and math concepts via applied learning, it can increase the students' ability to succeed in all types of STEM coursework (Stone et al., 2008). This becomes important when we consider students with LDs. Because students with LDs often struggle in traditional STEM courses, taking AS-CTE courses provides an additional (and new) learning opportunity to solidify previous material, which is being taught via a more accessible way, such as hands-on learning and labs (Plank et al., 2008; Scruggs & Mastropieri, 1993). In doing so, AS-CTE coursetaking may be a more efficacious way for students with LDs to solidify STEM content, hence making them more college ready in STEM fields of study.

The second mechanism is relevance and engagement. AS-CTE courses focus on applying math and science skills in practically-relevant ways and are designed to link high school STEM content to college as well as career (Gottfried & Bozick, 2016). Traditional STEM courses are abstract and often lack the ability to relate to these long-term perspectives, which can discourage students with LDs from persisting in these fields (Brigham et al., 2011; Shifrer et al., 2013; Therrien et al., 2011; Villanueva & Hand, 2011). In contrast, given their direct connection to real-world content delivered through hands-on experiences (Gottfried et al., 2014), AS-CTE courses may be one way to not only engage students with LDs in STEM material in ways that fit their unique learning needs, but these courses may also help students with LDs cultivate a stronger perspective on how STEM content is relevant after high school and into college (Stone & Lewis, 2012). There is evidence that participation in school-based career courses, such as AS-CTE, does link to measures of high school engagement—improved attendance, lower dropout rates, and more units earned (Plank et al., 2008; Plasman & Gottfried, 2018). Additionally, research has shown that students with LDs who took AS-CTE courses were more likely to enroll in college (Gottfried & Plasman, 2018). Hence, there is some evidence that AS-CTE courses at the very least promote students with LDs to persist in school in general. This study will further explore this mechanism by examining whether exposure to relevant STEM knowledge that intends to build an arc between STEM in high school and STEM in college may indeed help students with LDs to be more invested in continuing into the STEM pipeline in particular.

Finally, AS-CTE courses might promote new types of skill formation—activity-based and hands-on learning requires different skills compared to textbook-based learning. Research suggests that when high school students are exposed to traditional coursework and practical applications of STEM curriculum, they are better positioned to develop new skillsets and foster interests that are relevant to college and career (Stone & Lewis, 2012; Stone et al., 2008). Therefore, AS-CTE coursetaking may promote STEM skills and knowledge that have direct relevance to addressing challenges in STEM fields that students might face in college. Therefore, students may develop the skillsets necessary to continue with AS-CTE related fields of study in college.

Current study

The overall lack of knowledge about the pursuit of students with LDs in STEM fields beyond high school certainly limits our understanding of the best way to support college opportunities for this group of students (Moon et al., 2012; National Science Foundation, 2015). The National Center for Education Statistics (NCES) states that 6.4 million (approximately 13%) students in public schools receive special education services, and 35% of those students have a LD (NCES, 2016). Students with LDs represent the largest category among students with disabilities, yet the amount of research devoted to college STEM outcomes for this group of students is not representative of the size (Cortiella & Horowitz, 2014).

Previous work has examined AS-CTE coursetaking patterns (Gottfried et al., 2021; Theobald et al., in press) and the benefits of AS-CTE coursetaking for students with LDs (Gottfried & Sublett, 2018; Plasman & Gottfried, 2018), though no work has focused specifically on college STEM outcomes. While one previous study revealed that students with LDs who take AS-CTE courses are more likely to attend college within 2 years of high school (Plasman & Gottfried, 2018), little is known about the STEM pipeline from high school to college for this group of students. This is the first study to investigate whether a STEM pipeline exists for students with LDs.

From a policy perspective, the Perkins Act places emphasis on learning academic STEM skills and technical skills for high-wage, high-demand fields. The curriculum of AS-CTE courses fit that description, and evidence that participation in these courses for students without LDs have been supported as a way for students to remain in the STEM pipeline (Gottfried & Bozick, 2016). Perhaps the same is true for students with LDs, yet it currently has remained unexplored. With this in mind, AS-CTE courses may serve as a way to stimulate interest in STEM fields and better align opportunities in the STEM pipeline for students with LDs. Therefore, we asked the following research questions:

1. Does AS-CTE coursetaking in high school link to students with LDs' college enrollment?
2. Does AS-CTE coursetaking in high school link to students with LDs seriously considering and, ultimately, selecting a STEM major in college?

Method

Sample

To answer the research questions, this study relied on the High School Longitudinal Study of 2009 (HSLS) dataset developed by the National Center for Education Statistics (NCES) at the U.S. Department of Education. This dataset follows a national cohort of over 20,000 9th-grade students in more than 900 public and private schools across the United States throughout secondary and into postsecondary years. Fall 2009 was the baseline year for data collection, at which time survey questionnaires were administered to 9th-grade students along with their parents, teachers, school administrators, and school counselors in an effort to establish a complete record of a student's developmental and educational environment. A first follow-up was conducted in the spring of 2012 when the majority of the student cohort was in 11th-grade. A brief data collection update was conducted in the fall of the 2013 to gather information on high school completion status and college plans. Over the course of the 2013 to 2014 school year, NCES also collected full transcript data when the majority of the students had completed high school and the degree verification was complete. This transcript data included full information on each student's coursetaking history, thereby allowing us to identify AS-CTE coursetaking patterns for our sample of students. A second follow-up took place in 2016 when most of the sample had been out of high school for 3 years. Student surveys were administered across all four data-collection waves (2009, 2012, 2013, 2016). Parent surveys were conducted in the base year (2009), first follow-up (2012), and recontact update (2013).

Our sample included students with LDs. We identified students as having an LD based on parent responses to NCES as to whether a doctor, healthcare provider, teacher, or school official had ever diagnosed their child with a specific learning disability. From this variable, we created a binary indicator equal to 1 if the student was reported to have an LD, and 0 otherwise. Approximately 7% of the entire sample in the dataset was classified as having an LD according to the parent survey responses ($N = 1,380$). This is consistent with prior research that used other nationally representative data to explore students with LDs' high school coursetaking (Plasman & Gottfried, 2018; Shifrer & Callahan, 2010). Additionally, given the nationally representative sampling design of the HSLS dataset, this 7% figure is consistent with the national estimates at the time of the data collection (Spellings et al., 2006).

To perform our analyses, we used Stata/SE v. 16.0. To address missing values, we imputed 20 datasets to resemble the original distribution of observed variables (Royston, 2004), and imputed all variables used in the analysis. In the reporting of our results, per NCES rules, all sample sizes have been rounded to the nearest 10 to provide disclosure protection for the restricted-use data used in the analysis. Note that a probability weight provided by the HSLS: 2009 data set, W4W1STU, was used to ensure that estimates based on subsamples are representative of students across the United States. This weight was chosen because it accounts for survey item nonresponse from the base year and the second follow-up surveys, both of which provided data used in our analyses. Note that in this study, our sample is limited to only include students with LDs and adjusted for survey nonresponse, and included $N = 950$ observations.

AS-CTE Coursetaking

Critical to this study, NCES collected high school transcripts for students in the sample in 2013 when the students had completed high school and degree verification was complete. This transcript data included full information on each student's coursetaking history, thereby allowing us to identify AS-CTE coursetaking patterns for our sample of students. The transcript data were merged with the survey data at the student level to provide a comprehensive understanding that included data on all high school courses taken, credit accrual, and grades earned. These coursetaking files were available for approximately 94% of the students who participated in the original baseline year sample in 2009. Course record files were calibrated to indicate Carnegie units as a standardized measure of credits earned. One Carnegie unit is equivalent to a course taken every day, one period a day, for an entire school year.

Based on transcript data, we were able to identify the number of units taken by each student in engineering technology and information technology courses in high school. We combined these variables to create a continuous variable for AS-CTE units earned.

Outcomes

College enrollment. In the second follow up interview, HSLS recorded students' college enrollment status as of February, 2016. The timing of the students' college enrollment status was also noted, classifying students as a "Delayer," "Leaver," "Standard enrollee," or "Never enrolled" based on the completion of postsecondary credential as of February, 2016. For the purpose of this study, we collapsed this variable into one binary indicator. If a student was recorded as ever having enrolled in college, they were assigned a 1, and if they never enrolled in any postsecondary institution, 0.

Seriously considered major. From the second follow up interview in 2016, HSLS asked students what major or field of study they were most "seriously considering" when they first started college. The students were given 23 categories to choose from. We looked at two specific fields of study that fall within the AS-CTE taxonomy: engineering technology and information technology. Based on this variable, we created a binary indicator equal to 1 if the student reported having seriously considered an AS field of study (i.e., engineering technology or information technology), and 0 otherwise. We were also interested in whether or not the respondents were "seriously considering" entering into a non-AS STEM major (i.e., a STEM major in a field other than engineering technology or information technology). For this dependent variable, we relied on the same survey measure described above, and created a binary indicator equal to 1 if the students reported having seriously considered a non-AS-CTE STEM major, and a 0 otherwise. NCES classified majors using the U.S. Department of Education's Classification of Instructional Programs (CIP) taxonomy, 2010 edition, which provides a set of codes for defining postsecondary education programs. Using this classification, we followed the same procedures employed by NCES to identify STEM majors based on the classification used for the National Science Foundation SMART grant program, which includes mathematics, science, computer science, engineering, and related technologies.

Declared major. Based on the second follow up interview in 2016, we were able to determine the student's college degree major. The students were given 23 categories to choose from, and we were interested in two specific categories of majors, as above: AS and other non-AS STEM fields. Based on this variable, we created two binary indicators, one for AS majors of study, and one for other non-AS STEM fields of study, where the binary indicator was equal 1 if the student reported participating in either of the respective categories of majors, and 0 otherwise.

Covariates

Table 1 presents the list of control variables we use in this study—consistent with those that have been utilized in prior studies of CTE coursetaking (Gottfried, 2015; Gottfried et al., 2014; Adelman, 2006; Bozick & Dalton, 2013; Brody & Benbow, 1990; Lee & Frank, 1990; Long et al., 2012; Riegle-Crumb, 2006; Shifrer & Callahan, 2010; Wimberly & Noeth, 2005). These

Table 1. Descriptive Statistics.

	Students with LDs who took AS-CTE		Students with LDs who did not take AS-CTE	
	M	*SD*	*M*	*SD*
Student-demographic data				
Female	0.37	0.48	0.45	0.50
Race/ethnicity				
Hispanic	0.16	0.36	0.19	0.40
Black	0.15	0.36	0.18	0.39
Asian	0.05	0.22	0.03	0.17
Other race	0.10	0.31	0.11	0.32
English language learner	0.02	0.13	0.02	0.15
IEP	0.79	0.40	0.79	0.39
Family data				
Highest parental education				
High school or below	0.44	0.50	0.50	0.49
Advanced degree	0.18	0.38	0.15	0.35
Parental marriage status				
Single	0.07	0.26	0.08	0.28
Married	0.71	0.45	0.63	0.48
Socioeconomic status	−0.02	0.75	−0.09	0.72

(continued)

Table 1. (continued)

	Students with LDs who took AS-CTE		Students with LDs who did not take AS-CTE	
	M	*SD*	*M*	*SD*
Academic history and attitudes				
Most advanced math course taken in 8th grade				
Low academic	0.39	0.49	0.41	0.49
Middle academic	0.23	0.42	0.20	0.40
Advanced	0.01	0.11	0.01	0.07
Other math	0.10	0.30	0.11	0.31
9th grade math score	45.68	9.94	43.86	9.62
Overall GPA	2.47	0.69	1.99	1.06
Math efficacy	−0.05	0.94	−0.12	0.90
Science efficacy	−0.12	0.89	−0.12	0.81
Student occupational expectations by age 30				
Occupation in engineering field	0.05	0.21	0.02	0.14
Occupation in CIS field	0.03	0.17	0.01	0.12
Occupation in a different STEM field	0.02	0.17	0.05	0.22
School level characteristics				
Percent of school receiving free and reduced lunch	0.32	0.25	0.35	0.27
Percent of minority students	0.05	0.03	0.05	0.03
Percent of the school with ELL designation	0.04	0.07	0.04	0.07

(continued)

Table 1. (continued)

	Students with LDs who took AS-CTE		Students with LDs who did not take AS-CTE	
	M	*SD*	*M*	*SD*
Percent of school receiving special education services	0.12	0.09	0.13	0.10
School control				
Public	0.84	0.37	0.87	0.34
Private	0.04	0.20	0.07	0.25
School type				
Comprehensive high school	0.94	0.25	0.93	0.26
Charter school	0.03	0.16	0.03	0.16
Vocational and technical school	0.01	0.10	0.00	0.08
Urbanicity				
City	0.28	0.45	0.25	0.44
Suburb	0.37	0.48	0.40	0.49
Rural	0.24	0.43	0.25	0.43
N	490	490	460	460

variables include *student-demographic* data (gender, race/ethnicity, English language learner status, if the student had an Individualized Education Program at school); *family* measures (highest level of parental education, parental marriage status, socioeconomic status); students' *academic history and attitudes* (most advanced math course taken in 8th grade, 9th grade math score, total GPA, math efficacy scale created by NCES, science efficacy scale created by NCES, and indicator for the field in which the student expected to have an occupation in by age 30); and *school level* characteristics (percent of school receiving free and reduced lunch, percent of minority students, percent of school receiving special education services, percent of the student body who are English language learners, school control, school type, urbanicity of school).

Descriptive Statistics

Table 1 presents the means and standard deviations of the variables used in this analysis, differentiated by students with LDs who took AS-CTE courses in high school and students with LDs who did not, our comparison group. Looking across the two samples of students, there were some differences. Students with LDs who did take AS-CTE coursework in high school were more likely to have a higher 9th grade math score and overall GPA. In terms of self-reported STEM self-efficacy, students with LDs who did take AS-CTE coursework reported higher values of mathematics self-efficacy compared to students with LDs who did not take any AS-CTE courses in high school.

A final point to note is that both groups had a similar likelihood of being classified as having an individualized education plan (IEP). This was expected, as IEPs are designed for student with disabilities in order to describe the individual goals and support needed for each student. However, the slight difference may arise from the fact that parents may choose to forego an official LD designation or label due to worries about potential stigma (Riddick, 2000). As such, students whose parents were told their child had a LD but chose not formalize this label would not have an IEP on file at school. We chose this approach because students identified as having learning disabilities but who do not have the official LD label are likely to still benefit from the instructional practices and any potential accommodations provided through CTE learning (Vaughn & Linan-Thompson, 2003). Therefore, our study relied on parental responses as to whether their student had ever been classified as having an LD, rather than relying on IEP status. However, as shown in Table 1, the majority of students in both samples did also receive an IEP through their school, as would be expected.

Analytic Approach

Baseline model. We began our analyses with the following model to obtain ordinary least squares (OLS) results:

$$Y_{ij} = \beta_0 + \beta_1 AS_i + \beta_2 S_i + \beta_3 F_i + \beta_4 H_i + \beta_5 SCH_j + \varepsilon_{ij}$$

where Y represented our college outcome of interest for student *i* who had attended high school *j*. AS represented the number of AS-CTE units earned in high school. The predictors denoted by S, F, H, and SCH represented the sets of control variables described above, namely *student-demographic* data (S), *family* measures (F), *academic history and attitudes* (H), and *school level* variables (SCH). Finally, the error term was clustered by school to account for the nesting of students within high schools in order to place a higher standard on our estimates to help prevent a Type 1 error. Note that all models were run as linear probability models, given that the outcomes were binary.

Test of robustness. While OLS regression is useful for producing correlational information regarding general trends between AS-CTE coursetaking and college outcomes, there would be cause for concern if we compared our coursetakers and non-coursetakers and simultaneously if coursetakers are systematically different from non-coursetakers. From Table 1, it does appear that there may be some measurable differences between coursetakers and non-coursetakers. In other words, these students are choosing to enroll in AS-CTE courses, and the reasons underlying these choices might be related to the key variable of interest—AS-CTE coursetaking—as well as our college outcomes.

Propensity score matching (PSM) is one technique used for these issues (Rosenbaum & Rubin, 1985). This technique allows for the analysis of students in naturally occurring groups (i.e., coursetakers and non-coursetakers) but who display similar likelihoods of coursetaking based on their observed characteristics. Based on the comparison sample, the propensity score matching yields an average treatment effect on the treated (ATT), which is a more robust estimate of the true effect of AS-CTE coursetaking for students with LDs. In order to meet the assumptions of PSM and have a valid fit of the model, we could not use our key continuous predictor variable of AS-CTE units earned in high school. To meet the assumptions of the model, we created a binary indicator to measure participation in AS-CTE courses as opposed to the number of units earned. We measured AS-CTE participation as a single binary measure of having taken an AS-CTE course at any time during high school, and the variable was assigned a value of 1 if a student had ever taken an AS-CTE course, and otherwise a 0. Creating a binary measure is acceptable in our analysis, given that the majority of students with LDs in the sample took 1 course.

PSM occurs in two stages. In the first stage, we calculated the propensity score, or probability (ranging from 0 to 1), of participating in AS-CTE in high school. Rosenbaum and Rubin (1985) determined the proper strategy for calculating a propensity score, defined as P(Z), or the conditional probability that a student with a set of Z observable characteristics will participate in a given behavior—participating in AS in this case as predicted by the following equation:

$$P(AS) = Pr(AS = 1 \mid Z).$$

The Z represents all of the control variables that were previously used to model the AS-CTE coursetaking in the OLS model: $\beta_2 S_i + \beta_3 F_i + \beta_4 H_i + \beta_5 SCH_i$ as written above.

The second stage of PSM matches students who did and did not participate in AS-CTE courses based on having similar propensity scores. The treatment effect of participation in AS-CTE is estimated by comparing the outcomes of treated and untreated students in the matched sample. The difference between the outcomes for these two groups of students is averaged across all matches, resulting in the ATT for the entire sample. While there are numerous PSM methods, we focus on kernel matching, which allows for multiple matches by pairing a member of the treatment group to multiple members of the control groups within a certain bandwidth based on their propensity scores (Heckman et al., 1997, 1998). This allows for control cases to be matched with multiple treatment cases. In kernel matching, a control case is given more weight if its propensity score is closer to that of a treatment case (Smith & Todd, 2005). This technique is useful for maintain statistical significance because of the number of treatment and comparison cases.

Results

College Enrollment

Table 2 presents the findings related to college enrollment estimates from the baseline model described above. The coefficients represent the probability of a student having enrolled in college. Coefficients are presented with clustered standard errors in the parentheses below each coefficient estimate. Recall the sample includes all students with LDs, and the comparison is between coursetakers and non-coursetakers. All independent variables are labeled in the

Table 2. OLS Estimates of College Enrollment for Students with LDs.

	Enroll in college
Key predictor	
AS-CTE Credits	0.01 (0.03)
Student-demographic data	
Female	0.06 (0.04)
Race/ethnicity	
Hispanic	0.04 (0.06)
Black	0.03 (0.06)
Asian	0.18* (0.09)
Other race	−0.06 (0.06)
English language learner	0.16 (0.13)
IEP	−0.19** (0.07)
Family data	
Highest parental education	
High school or below	−0.09 (0.07)
Advanced degree	−0.00 (0.07)
Parental marriage status	
Single	0.04 (0.08)
Married	0.02 (0.05)
Socioeconomic status	0.12* (0.05)
Academic history and attitudes	
Most advanced math course taken in 8th grade	
Low academic	−0.03 (0.05)
Middle academic	−0.10 (0.06)
Advanced	−0.04 (0.16)
Other math	−0.15* (0.06)
9th grade math score	0.00 (0.00)
Overall GPA	0.15*** (0.03)
Math efficacy	0.05* (0.02)
Science efficacy	−0.02 (0.02)
Student occupational expectations by age 30	
Occupation in engineering field	−0.04 (0.11)
Occupation in CIS field	0.03 (0.12)
Occupation in a different STEM field	0.46*** (0.13)
School level characteristics	
Percent of school receiving free and reduced lunch	−0.00 (0.00)
Percent of minority students	−0.00 (0.01)
Percent of the school with ELL designation	0.00 (0.00)
Percent of school receiving special education services	0.00 (0.00)

(continued)

Table 2. (continued)

	Enroll in college
School control	
Public	−0.23*** (0.06)
Private	0.02 (0.09)
School type	
Comprehensive high school	0.03 (0.10)
Charter school	0.23 (0.15)
Vocational and technical school	0.13 (0.12)
Urbanicity	
City	0.12 (0.07)
Suburb	0.12 (0.07)
Rural	0.14* (0.07)
N	950

Note. Robust errors adjusted for school clustering are in parentheses.
*$p < .05$. **$p < .01$.***$p < .001$.

Table 3. OLS Estimates of Serious Consideration of Major for Students with LDs.

	Seriously consider AS major	Seriously consider non-AS STEM major
AS-CTE credits	0.07** (0.02)	−0.01 (0.01)
N		

Note. Robust errors adjusted for school clustering are in parentheses.
*$p < .05$. **$p < .01$. ***$p < .001$.

first column of the table, with the first variable representing our key measure of AS-CTE units earned in high school. The AS-CTE units coefficient in the model represents the difference in AS-CTE units earned for students with LDs when holding all else constant. In our baseline model estimating expectations of attending college, we found no evidence suggesting that students were more or less likely to enroll in college with respect to AS-CTE units earned. In other words, college enrollment looks very similar for students regardless of whether or not they had earned any AS-CTE units in high school.

Table 4. OLS Estimates of Declaration of Major for Students with LDs.

	Declare AS major	Declare non-AS STEM major
AS-CTE credits	0.06* (0.02)	−0.01 (0.01)
N		

Note. Robust errors adjusted for school clustering are in parentheses.
*$p < .05$. **$p < .01$. ***$p < .001$.

STEM Major

Seriously considered major. Table 3 presents findings indicating if students seriously considered an AS or non-AS STEM major or field of study when they first entered college. Each column represents a unique regression, where the outcome is designated at the top of the columns. The coefficients represent the probability of a student reporting that they seriously considered the major designated at the top of the column. Coefficients are presented with clustered standard errors in the parentheses below each coefficient estimate. Note that in this table, only the AS-CTE coefficient is presented—equivalent to the top row of coefficients in Table 2. All other variables are included in the model, as per Table 2, though they are not shown for the sake of parsimony.

The first column of results presents the probability of a student having seriously considered an AS major or field of study in college with respect to AS-CTE units earned in high school. Students with LDs who earned units in AS-CTE courses were 7 percentage points more likely to seriously consider an AS major in college. Practically speaking, as students with LDs earned more units in AS-CTE courses, they were more likely to seriously consider majoring in engineering technology or information technology fields of study in college.

We were also interested in whether AS-CTE units earned in high school could predict if students would seriously consider a non-AS STEM major (i.e., a STEM major in a field other than engineering technology or information technology). The second column of results represents the probability of a student seriously considering a non-AS STEM major in college. Students who earned AS-CTE units were no more or less likely to seriously consider a non-AS STEM major in high school when compared to students who did not earn any AS-CTE units.

Declared major. Table 4 presents the findings related to the probability of students with LDs declaring an AS or non-AS STEM major in college. Again, each column represents a unique regression, where the outcome is designated

Table 5. OLS and Matching Estimates of AS-CTE Coursetaking to College Outcomes.

AS-CTE vs. No AS-CTE	(1) OLS	(2) Kernel
College enrollment		
Attend college	0.01 (0.03)	0.03 (0.04)
Seriously consider major		
AS major	0.07** (0.02)	0.05*** (0.01)
Non-AS STEM major	−0.01 (0.01)	0.00 (0.02)
Declare major		
AS major	0.06* (0.02)	0.05*** (0.01)
Non-AS STEM major	−0.01 (0.01)	0.01 (0.02)
N		

Note. Standard errors in parentheses.
*$p < .05$. **$p < .01$. ***$p < .001$.

at the top of the columns. The coefficients represent the probability of a student declaring a specific major, designated at the top of the column. Coefficients are presented with clustered standard errors in the parentheses below each coefficient estimate. Again, only the AS-CTE coefficient is presented. All other variables are included in the model, as per Table 2, though they are not shown for the sake of parsimony.

Across all both of our models in Table 4, we found statistically significant results pertaining to declaring a STEM major with respect to AS-CTE coursetaking. The first column of results presents the findings related to declaration of an AS major with respect to AS-CTE coursetaking in high school. We found that students who earned units in AS-CTE were 6 percentage points more likely to declare an AS major in college. With respect to declaring a non-AS STEM major, column 2 presents findings that students who earned units in AS-CTE in high school were 2 percentage points *less* likely to declare a non-AS STEM major in college. In other words, students with LDs who earned units in AS-CTE courses were more likely to declare AS majors in college, but less likely to declare a non-AS STEM major (i.e., a STEM major in a field other than engineering technology or information technology).

Tests of Robustness

Table 5 provides the ATT associated with AS-CTE participation and our college outcomes. Column 1 provides OLS estimates from Tables 2 to 4 for reference, and column 2 illustrates the estimates for the kernel matching technique. There is one key takeaway from the results of the propensity score matching.

Namely, there is consistency between baseline and matching models. There is still no link between AS-CTE coursetaking and college enrollment or having seriously considered or declared a non-AS STEM major. Additionally, the PSM results indicate that there is still is a significant, positive link between AS-CTE coursetaking and serious consideration/declaration of an AS major for students with LDs. Namely, students who earn units in AS-CTE are 5 percentage points more likely to seriously consider an AS major upon entry to college, and 5 percentage points more likely to declare an AS major.

Discussion

Given the continued policy concerns about the growing STEM achievement gap for students with LDs (National Science Foundation, 2015), and the lack of representation of students with LDs in the STEM pipeline (Moon et al., 2012), the purpose of this study was to examine the potential of AS-CTE coursetaking to bridge the secondary-to-postsecondary STEM pipeline for students with LDs. Previous research investigating the link between high school coursework and STEM college major has generally focused on traditional STEM courses, like calculus, physics, and so forth (Adelman, 2006; Federman, 2007; Long et al., 2012; Trusty, 2002). That said, the abstract nature of these traditional STEM courses and reliance on text-based instruction and memorization can be a significant struggle for students with LDs (Powell et al., 2013; Scruggs et al., 2013; Shifrer et al., 2013). In contrast, AS-CTE courses focus on applying math and science skills in more hands-on, relevant ways, which may serve as a means to support skill formation and interests to sustain the pursuit of STEM for students with LDs.

Research has previously showcased the benefits of AS-CTE coursetaking on high school outcomes for students with LDs (Plasman & Gottfried, 2018; Gottfried & Sublett, 2018; Shifrer & Callahan, 2010). Yet, there remains a gap in evidence on the longer-term influence that these high school AS-CTE courses might have on college outcomes. Based on evaluating data from a national sample of high school students collected after the key 2006 reauthorization of the Carl D. Perkins Career and Technical Education Act—which emphasized a need for CTE classes to provide students (and particularly those with disabilities) with the academic and technical skills needed to continue through the STEM pipeline—our analyses were the first to use the most currently-available nationally representative data to investigate the link between AS-CTE coursetaking and college enrollment, serious consideration of a STEM major, and ultimate declaration of a STEM major in college for students with LDs.

As for our first research question, we found that taking more AS-CTE units did not link to college enrollment for students with LDs. This is not necessarily a negative finding, because AS-CTE courses are designed to prepare and motivate students in STEM with proper skills to continue through the STEM pipeline—and not necessarily through the K-16 pipeline more broadly. That is, college enrollment is a very general outcome (and perhaps beyond the scope and intention of CTE coursetaking), and our findings indicate that participation is not related to college enrollment.

Importantly, the results of our second research question show evidence of an AS secondary-to-postsecondary pipeline. Students with LDs who earned more AS-CTE units in high school were more likely to seriously consider an AS major when they first entered college, and they were additionally more likely to declare an AS major (engineering technology or information technology) in college compared to students with LDs who took fewer AS-CTE units. These results provide evidence that students who take AS-CTE courses are persisting in AS fields of study after graduating high school and into college, hence providing evidence of an AS pipeline for students with LDs.

Of importance, we found no evidence that AS-CTE coursetaking predicts any link to non-AS STEM majors. Although we were not able to find a link between AS-CTE coursetaking and serious consideration/declaration of a non-AS STEM major in college, this is not necessarily a negative finding. Given that AS-CTE courses are designed to engage students in AS material (i.e., engineering technology and information technology), this appears to be translating into students continuing to explore these specific STEM fields of study in college.

Limitations

As with most analyses of existing datasets, there are several limitations to this study that could encourage future research in this area. First, while HSLS: 2009 allowed us to determine whether or not students with LDs had earned units in AS-CTE courses in high school, the data set does not provide information on the full CTE offerings at each school. Therefore, we were unable to control for how many AS-CTE course offerings the students had access to. Future research might explore the different AS-CTE coursetaking options available at high schools in the U.S., and how this relates to STEM pipeline outcomes for students with LDs.

Second, while HSLS: 2009 provided sufficient information regarding AS-CTE coursetaking, college-going expectations, and serious consideration/declaration of STEM majors, it is not possible to draw any empirical conclusions about the mechanisms behind those decisions. Future research should consider qualitative approaches to understand the STEM engagement and motivation related to enrollment in AS-CTE courses, in addition to the motivating factors behind the choice to pursue or abstain from entering into STEM related fields of study in college.

Third, while HSLS: 2009 provides information on the courses taken by each student, it does not contain specific information related to course content and instructional practices used in AS-CTE courses. Future research should consider exploring the specific aspects of course contexts, including rigor, quality, and instructional practices in these courses, and how these factors may relate to a student's decision to persist in STEM after high school and into college.

Finally, while this study examined students who pursued college in AS and non-AS STEM areas of study, we did not asses the outcomes for students who did not go to college. Future research might consider employment outcomes for students with LDs across STEM fields and determine whether a similar AS pipeline exists.

Implications

Given the recent push for AS-CTE classes to provide students with the academic and technical skills in STEM necessary for college and employment in high skill, high wage, and high demand careers, the results of this study are very promising. Students with LDs represent a key population of students that have been historically underrepresented in engineering technology and information technology (STEM in general) fields, and AS-CTE coursetaking may be a key factor linked to developing pathways in STEM fields.

Considering the findings from our research questions together, there are several key implications for policy and practice. A recent goal of policy makers has been to equalize STEM access and participation for all students, and policies like Perkins have attempted to attenuate the underrepresentation of students with LDs in STEM fields though the expansion of AS-CTE coursework. Yet, most research on the 'efficacy' of AS-CTE coursework and policies have focused on high school outcomes. In order for educational policy makers to fully understand the full effects of AS-CTE coursetaking for students with LDs, they must understand how these effects are relevant at multiple steps throughout the STEM pipeline (e.g., transition into college and during college). Understanding the effects of AS-CTE coursetaking on the college degree selection process more completely will make for more well-informed policy decisions that promote success and persistence in STEM for students with LDs.

Our study shows evidence of a AS pipeline from high school to college. If a goal of policymakers is to sustain this pipeline, then policymakers and school districts might consider which supports are needed to sustain these pipelines, such as scaffolding. For instance, participation in early, introductory STEM courses may complement later AS-CTE coursework in high school. Hence, increasing participation rates in early courses may support the persistence of students with LDs AS-CTE courses later in high school, and broaden the population of students who could pursue STEM fields of study in college. Other supports for students with LDs may come from school counselors, who are in a unique position to influence decisions related to high school course planning, high school graduation, and college coursetaking (Goodman-Scott et al., 2018). School counselors have the ability to inform students and parents about the high school, college, and career related benefits of AS-CTE coursetaking. By making students and other key players aware of the short- and long-term benefits of AS-CTE coursetaking, counselors could help increase access across multiple areas of STEM, both applied and academic, for students with LDs.

These implications thus far, however, assume that schools can offer AS-CTE courses. We must address the fact that some schools may not have AS-CTE courses. If high schools do not have AS-CTE courses available for students, we would urge for exploring how teachers in traditional STEM courses might use AS-CTE instructional practices in their classrooms—though this would be a call for future research, given that instructional practices were not available in our data. We hypothesize, though, that the application of academic concepts to address real-world STEM problems by incorporating "hands on" lessons, logic, and problem-solving skills may serve as a support to bolster engagement and performance of students with LDs, even in traditional STEM courses. By providing students with learning opportunities that meet their unique learning needs, students may gain perspective on how STEM content is relevant after high school and into college.

Conclusion

Given the investment of the Perkins legislation to support students with disabilities in STEM fields through access to STEM-themed CTE coursework, the results of this study are encouraging. Our findings add to the growing body of empirical research related to the potential benefits of AS-CTE coursetaking for students with LDs, and we are the first to expand the literature to encompass college STEM outcomes using the most recent data available. Unlike prior studies that focus on the deficits of students with LDs in STEM, our findings suggest that an AS pipeline exists for these students and that AS-CTE coursetaking may be a potential mechanism to aid in STEM pipeline persistence by this key population of students.

In closing, this was the first study to use the most current data available to investigate whether AS-CTE coursetaking in high school may influence students' postsecondary interests and pursuits in STEM. This study has shown that high school students with LDs who took more AS-CTE units in high school were more likely to seriously consider, and ultimately declare AS majors in college. However, this relationship was not evident for non-AS STEM majors. Given that AS-CTE courses are designed to develop skills and promote persistence in AS fields of study, this is not necessarily a negative finding considering the high demand in AS-related careers such as software developers and renewable energy technicians. Ultimately,

Appendix 1. Taxonomy of Career Clusters in CTE.

Agriculture, food, and natural resources
Architecture and construction
Arts, audio-video technology and communications
Business, management, and administration
Education and training
Finance
Government and public administration
Health science
Hospitality and tourism
Human services
Information technology
Law, public safety, corrections, and security
Manufacturing
Marketing, sales, and service
Science, technology, engineering, and mathematics
Transportation, distribution, and logistics

Source. Advance CTE (https://careertech.org/career-clusters).
Note. Engineering technology courses are categorized within the science, technology, engineering, and mathematics career cluster. For the purpose of this study, we disaggregated engineering technology courses.

identifying the long-term career and employment outcomes of individuals with LDs in AS fields will indicate the true benefits of AS-CTE participation.

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ORCID iDs

Jennifer A. Freeman https://orcid.org/0000-0001-7312-6833
Jay Stratte Plasman https://orcid.org/0000-0003-1071-8270

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Author Biographies

Jennifer A. Freeman is a PhD student in the Graduate School of Education at the University of Pennsylvania. Her research interests lie in educational policies that promote college and career readiness for underrepresented populations in STEM, particularly students with learning disabilities and community college transfer students.

Michael A. Gottfried is an associate professor in the Graduate School of Education at the University of Pennsylvania. His research interests focus on education policy and the economics of education.

Jay Stratte Plasman is an assistant professor in the College of Education at The Ohio State University. His interests focus on career and technical education and education policy.