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Trending Up: A Cross-Cohort Exploration of STEM Career and Technical Education Participation by Low-Income Students

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ABSTRACT
The ink from the reauthorization of the Perkins Act – the federal policy governing career and technical education (CTE) – in the summer of 2018 is still fresh. This much-needed update builds upon some of the major tenets of the 2006 version, including emphases on increasing the participation of low-income students in CTE and encouraging CTE coursework that focuses on building math and science skills while also providing technical skills for participation in high-skill, high-demand careers. Using two nationally representative datasets, in between which the 2006 Perkins Act was reauthorized, we explore whether there were any observable differences in participation in these math and science based CTE courses by low-income students over time. Implications are discussed.

Introduction

In 2006, the federal government reauthorized the Carl D. Perkins Career and Technical Education Improvement Act to continue funding career and technical education (CTE) across the country. In this reauthorization were two particularly important emphases regarding targeted student groups and targeted areas of study. First, low-income students – identified in Perkins IV as "individuals from economically disadvantaged families" – were highlighted as one of the groups specifically targeted to receive CTE programing to prepare them for high skill, high wage, and high demand careers. Second, the Perkins Act identified a need for CTE coursework to provide students with the academic and career and technical skills particularly in science, technology, engineering, and mathematics (STEM) fields, given the growth in employment in these fields. Taken together, policymakers made it clear that there is need to increase the participation of low-income students in CTE coursework, especially in STEM (Bell, Chetty, Jaravel, Petkova, & Reenen, 2017; Bragg, Kim, & Barnett, 2006).

The Perkins IV focus on increasing the rigor and relevance of CTE coursework by emphasizing growth in both academic and career skills, particularly in mathematics and science was accompanied by increased attention on the importance of the role

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of technology in CTE. This shift in CTE focus to fit more closely with the ever-growing academic achievement demands while also exploring practical experiences means CTE is now capable of meeting the demands of all students – those who are preparing for postsecondary education as well as those planning to enter the labor market immediately after high school. With the additional focus on increasing participation for low-income students among other special populations (e.g. students with disabilities, and individuals preparing for nontraditional training and employment such as females in STEM fields), policymakers underscored their desire to improve CTE coursetaking for all students. Considering the growing focus on providing students with industry-recognized credentials through completion of a concentration, and the benefits associated with concentration, the Perkins reauthorization included language implying students should participate in CTE coursework throughout the course of high school careers and also complete multiple units in a particular cluster to show mastery and receive an industry-recognized credential (Dougherty, 2016).

Thanks to the timing of the 2006 Perkins reauthorization – between the collection of two national, longitudinal datasets – we are able to explore changes in CTE coursetaking that may relate to this reauthorization. Two nationally representative datasets were collected for secondary students falling on either side of this reauthorization. The high school class of 2004 cohort experienced CTE as it was outlined under Perkins III, while the high school class of 2013 would have seen CTE programing as designed and funded by Perkins IV. We are therefore able to explore CTE coursetaking patterns over time to observe whether Perkins IV may be helping shift the needle of CTE participation for low-income students. It is, however, important here to note that we were not looking for a causal relationship, nor to make causal claims about Perkins IV and these coursetaking patterns. We were more interested in observing whether any differences were aligned with the Perkins IV goals.

The importance of STEM and the role of STEM-focused CTE

STEM education has become an important focus for the federal government over the past few decades. At the time of the Perkins reauthorization, STEM fields were identified as "areas of national need" in order to improve the nation's competitive standing within the international arena (Goan, Cunningham, & Carroll, 2006). Since the reauthorization, many argue there is still a shortage of STEM trained individuals (ACT, 2013; National Academy of Sciences, 2007; Olson & Riordan, 2012), though there is no agreement on this issue (Charette, 2013; Stevenson, 2014; Teitelbaum, 2014). However, researchers agree that increasing STEM-related careers can play a critical role in boosting the economy and will continue to do so in the future (Xue & Larson, 2015). Aside from these macroeconomic benefits, STEM-related careers may also provide an opportunity for individual gains, given that these fields tend to have employment trajectories in high-skill, high-wage careers (Jacobson & Mokher, 2009). Though STEM fields tend to offer high-wage employment opportunities in high demand fields, they also require relatively high levels of specialized skills. Therefore, with the potential for STEM careers to offer high wage jobs, encouraging low-income students to participate in STEM-based coursework could provide one potential path out of poverty as they transition into college and/or career (Bell et al., 2017).

Given these individual and national benefits of fostering skills in STEM fields, the 2006 Perkins Act reauthorization placed an emphasis on STEM-focused CTE – hereafter referred to as AS-CTE to represent applied STEM CTE – following on the heels of a declared STEM labor market shortage (National Science Board, 2012; National Science Foundation, 2013). Under the broad category of CTE, the US Department of Education identifies AS-CTE courses as falling into two STEM related fields: engineering technology and information technology (Bradby & Hudson, 2007). The design of AS-CTE courses under Perkins IV is meant to link high school STEM learning to college and career training by connecting the more abstract and theoretical material taught in academic STEM courses with more practical, real-world instruction in AS-CTE courses (Brand, Valent, & Browning, 2013; Plasman & Gottfried, 2018).

In the research base in this area, there are three theorized mechanisms by which AS-CTE may benefit students, which may help to clarify why Perkins emphasized STEM in the reauthorization: new skill growth, academic skill augmentation, and engagement and relevance (Gottfried, 2015; Gottfried, Bozick, & Srinivasan, 2014; Plank, DeLuca, & Estacion, 2008). First, by participating in AS-CTE courses, students can gain new career skills directly related to engineering and information technology fields (Brand, Valent, & Browning, 2013; Schargel & Smink, 2001). AS-CTE students also gain skills related to problem solving, logical reasoning, and critical thinking. Second, AS-CTE coursework also provides hands-on learning experiences. By emphasizing real-world learning techniques, AS-CTE helps to build upon concepts learned in traditional STEM courses, thereby enhancing overall learning (Brand et al., 2013). Finally, the practical learning in AS-CTE courses helps to connect high school learning more directly – helping students to see the relevance of their high school education – to postsecondary opportunities (Bozick & Dalton, 2013). When students can see the direct relevance of their education, they tend to feel more engaged in school in general (Stone & Lewis, 2012).

Through these three mechanisms, previous research has connected AS-CTE with numerous other positive outcomes at secondary, postsecondary, and career levels. At the secondary level, AS-CTE coursetaking has been linked to higher odds of taking advanced math and science courses and higher math achievement levels (Bozick & Dalton, 2013; Gottfried, 2015; Gottfried et al., 2014; Stone, Alfeld, & Pearson, 2008). Additionally, students who participate in AS-CTE courses are more likely to graduate from high school (Plasman & Gottfried, 2018). Further research into the relationship between CTE coursetaking and graduation found that courses taken during different years in high school actually had different associations with eventual graduation (Gottfried & Plasman, 2018b). At the postsecondary level, AS-CTE is connected to increased likelihood of pursuing STEM studies in college (Gottfried & Sublett, 2018). Previous studies have also established a direct pathway link between AS-CTE coursework in high school and coursetaking and eventual credentialing in AS-CTE in postsecondary education (Plasman, Gottfried, & Sublett, 2017). Finally, previous research found that students who concentrate in AS-CTE (i.e. complete one and half units or more AS-CTE courses) in high school earn significantly more in later careers than do students who do not concentrate in a CTE cluster (Dougherty, 2016).

As-CTE benefits for subgroups of students

While there is no empirical evidence regarding the AS-CTE coursetaking effects specifically for low-income students, there is reason to believe the mechanisms above still relate to this population of students and may indeed have a larger impact for low-income students in some respects. Regarding new skill growth, many low-income students do not have support outside the school to help them learn skills necessary to succeed in postsecondary education or in the pursuit of STEM fields and high school AS-CTE courses were designed to build college-readiness skills (Brand et al., 2013; Oakes & Saunders, 2008; Partnership for 21st Century Skills, 2010; Stern & Stearns, 2006). These AS-CTE courses also have the potential to have a more profound impact in helping to enhance STEM-specific skills for low-income students because of lower teacher capability to serve students from lower-income backgrounds in traditional STEM classes (Darling-Hammond, 2000). AS-CTE courses may help to fill in some of the gaps for these students. Finally, low-income students as a group tend to be disengaged from school, and may therefore benefit more from participation in particularly engaging courses, as AS-CTE are designed to be (Stone et al., 2008; Stone & Lewis, 2012).

There is no existing study on the AS-CTE coursetaking of low-income students; however, previous research has examined AS-CTE coursetaking for other subgroups. For instance, students with disabilities were found to benefit from taking AS-CTE courses in high school – they have higher odds of graduating courses and this benefit was greater than for students without disabilities who took the same types of courses (Plasman & Gottfried, 2018). This relationship may be particularly beneficial to students with disabilities, given the first mechanism mentioned above – because of the hands-on learning approach in AS-CTE courses, students with disabilities performed better when developing new schools through this applied, rather than theoretical, approach (Brigham, Scruggs, & Mastropieri, 2011; Jenson, Petri, Day, Truman, & Duffy, 2011; Moon, Todd, Morton, & Ivey, 2012; Scruggs, Mastropieri, Bakken, & Brigham, 1993).

Research has also examined AS-CTE by gender. In one specific cluster of AS-CTE – engineering technology – female students were found to benefit more from taking these courses in high school than male students – that is, females who took engineering AS-CTE courses in high school experienced a greater boost in the chances of completing an engineering degree in postsecondary education than did males (Gottfried & Plasman, 2018a). This research provides evidence that certain areas of CTE may help to close the existing gap between males and females in STEM-related fields (US Census Bureau, 2014).

This body of previous literature points to the numerous positive benefits of participation in AS-CTE. These benefits are particularly pronounced for specific subgroups in some cases (e.g. students with disabilities and high school graduation and female students pursuing engineering credentials) and may assist in helping close achievement gaps for these groups. However, research has not yet explored the benefits of AS-CTE specifically in relation to low-income students as a subgroup. This group of students is less likely to come have a parent in a STEM-related field, thereby reducing the potential for home-based STEM exposure (Yelamarthi & Mawasha, 2008). Therefore, increasing access and exposure to AS-CTE courses for low-income students has the potential to exhibit particularly strong effects.

Study purpose

Considering the numerous benefits associated with AS-CTE coursetaking, the Perkins IV identified desire to increase CTE coursetaking for "special populations," and the national need to increase the STEM labor market, understanding the changes in AS-CTE coursetaking by low-income students is an important step in helping to evaluate whether the nation has progressed in this regard before-and-after a policy reauthorization. In particular, knowing if low-income students are taking more courses deemed as beneficial is critical because of the benefits associated with participation as well as potential employment benefits from the specific skills gained. In order to fill this need, we posed the following research questions:

1. How has AS-CTE coursetaking for low-income students changed between 2004 grad class and 2013 grad class – that is, before and after the 2006 Perkins reauthorization?
2. Are there changes in the timing of when students take these courses in high school?
3. Do female low-income students or low-income students with disabilities exhibit specific changes in AS-CTE coursetaking?
4. How do changes in AS-CTE coursetaking compare to other popular CTE clusters?

To answer these questions, we utilized two different nationally representative datasets. To examine the class of 2004, we used the Education Longitudinal Study of 2002 (ELS). This dataset followed a cohort of students who were 10th graders in 2002 as they moved through high school and beyond. The High School Longitudinal Study of 2009 (HSLS) provided data for the high school graduating class of 2013. In this dataset, students were in the 9th grade in 2009 and were followed throughout high school, with plans to continue following this group of students through college and into career.

In answering the first question, we were able to provide evidence regarding how the Perkins Act reauthorization may relate to coursetaking changes in AS-CTE for low-income students. The findings from this question have the potential to help guide CTE policymakers and educators in facilitating access to AS-CTE courses in schools for all students. Additionally, our results provide evidence as to whether low-income students are falling behind in their pursuit of STEM learning through alternative pathways (i.e. AS-CTE). Given the benefits associated with AS-CTE coursetaking, an observed decrease in STEM-related coursework over time for low-income students could have the potential to exacerbate preexisting socioeconomic stratification.

Previous research identified the importance of accounting for the timing of when CTE classes are completed (Gottfried & Plasman, 2018b). Early coursework may serve as scaffolding as students supplement the skills learned in traditional STEM courses. Later coursework, meanwhile, may promote the relevance of secondary coursework as students approach graduation. With the language in Perkins IV focusing on industry-recognized credentialing, it becomes necessary to observe whether there are changes in the timing of coursework in high school. Therefore, a response to our second research question allowed us to determine when students in a more recent graduating class are participating in AS-CTE. Engaging low-income students in these courses later in high school may be particularly important because of the relationship between later CTE coursetaking and eventual high school graduation for a group of students traditionally at risk of dropping out (Rumberger, 2001; Rumberger & Lim, 2008).

Our third research question allowed us to identify any potential changes for specific subgroups of low-income students – subgroups that have been previously explored in the AS-CTE literature. Finally, responding to our final question enabled us to determine whether any changes in AS-CTE coursetaking are unique to that area of CTE or whether similar patterns are present in other CTE categories as well. This is of particular interest because the specific Perkins IV language identifying the need to focus on academically rigorous math and science CTE coursework. Additionally, changes in labor market demands have shifted toward those careers that require skills such as those gained by participation in AS-CTE courses (Bureau of Labor Statistics, 2013). Again, it is important to note that we do not expect to make any causal claims about Perkins IV and AS-CTE coursetaking changes.

Method

Dataset overview

To answer our research questions, we merged two nationally representative datasets that contained identical measures of a wide range of student demographic and academic variables – the first was collected prior to the 2006 Perkins reauthorization, while the other was collected after the implementation of Perkins IV. The first dataset is the Education Longitudinal Study of 2002 (Ingels et al., 2014) and the second is the High School Longitudinal Study of 2009 (Ingels et al., 2015). We utilized the restricted versions of these datasets and analyzed the data using Stata 15.

The final analytic sample included only those students who had complete transcript data. To address missing data concerns related to other variables, we used a multiple imputation technique to impute 20 additional datasets (Graham, Olchowski, & Gilreath, 2007). To ensure imputed data remained representative to each dataset, we imputed separately across each dataset and then merged the datasets together. After imputation, our final analytic sample across both datasets included 36,700 students, of which 13,900 were identified as low-income – 8400 (44% of HSLS) from HSLS and 5500 from ELS (43% of ELS). We defined low-income in this paper as twice the federal poverty threshold (i.e. $36,200 for a family of four in 2002; and $44,100 for a family of four in 2009) as identified by the National Center for Children in Poverty (Jiang, Ekono, & Skinner, 2015). All of our analyses below focus on low-income students. All sample sizes have been rounded to the nearest ten as per NCES guidelines.

Outcomes

We have identified outcome variables that fall into two broad AS-CTE coursetaking categories: participation and unit completion. Within these categories, we included outcomes by cluster (e.g. ET and IT) and by school year (i.e. freshman, sophomore, junior, or senior year). With respect to our first research question, we were interested in whether students in the graduating class of 2013 (HSLS) were more likely to participate in AS-CTE than were students in the class of 2004 (ELS). We therefore identified whether an individual student participated in any AS-CTE coursework in high school, as well as whether participation was limited to either engineering technology (ET) or information technology (IT) clusters as identified using course codes (Bozick & Dalton, 2013; Bradby & Hudson, 2007; Sublett, 2016). To respond to our second research question, we also tracked whether students participated in these courses during freshman, sophomore, junior, or senior year. The participation variables were coded as binary indicators identifying whether a student completed at least one AS-CTE (or ET or IT) course during the given time period, with 1 indicating participation and 0 indicating no participation. We also explored whether students were completing more AS-CTE coursework in the class of 2013 by examining the total number of AS-CTE units students completed. Again, we broke these out by cluster and year in school. These outcomes were identical in our subgroup analyses as presented in our third research question.

In an effort to respond to our final research question, we included additional variables to compare AS-CTE unit completion to completing units in other CTE areas based on prior research showing CTE cluster specific pathways between secondary and postsecondary (Plasman et al., 2017). First, we created a ratio comparing the number of units completed in AS-CTE to the total number of CTE units earned. We also created variables identifying unit completion in five additional CTE categories: agriculture and natural resources, business, communications, health, and manufacturing. These additional categories were the most populous CTE groups across both samples.

Control variables

ELS and HSLS include socio-demographic, academic, and school variables that were common across the two datasets. Descriptive statistics for these variables are presented in Table 1. The first column describes the data cross both datasets. The second column restricts the sample to our population of interest – low-income students. Columns three and four break out the descriptive statistics for low-income students by dataset membership – either ELS or HSLS. As shown in Table 1, across the sample of low-income students, 55% participated in AS-CTE and completed an average of 0.64 units. Within the ELS sample, 50.1% participated in AS-CTE at any point in high school and averaged 0.54 earned units. In HSLS, 58.3% participated in AS-CTE courses in high school and earned an average of 0.71 units.

Beyond AS-CTE variables, the set of control variables fell across the three main categories mentioned above: socio-demographic, academic attitudes and history, and school variables. Socio-demographic data included gender, race/ethnicity, family arrangement, and socioeconomic status. Academic variables included whether a student had an individualized education plan (IEP) on file, 9th grade GPA, number of academic units, standardized math score, math self-efficacy, and postsecondary expectations. Finally, school variables included the following: percent of minority students, percent of English language learner (ELL) students, and a measure of urbanicity. These variables selected based on previous research focusing on AS-CTE coursetaking (Bozick & Dalton, 2013; Sublett, 2016; Tyson, Lee, Borman, & Hanson, 2007). A majority of these variables were obtained through the base-year surveys. However, there are some exceptions. Math self-efficacy was taken from the first follow-up survey from both ELS and HSLS, and our

Table 1. Descriptive statistics.

	Full sample		Low-income		Low-income ELS		Low-income HSLS	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
AS-CTE participation	0.55	(0.50)	0.55	(0.50)	0.50	(0.50)	0.58	(0.49)
AS-CTE units	0.63	(0.92)	0.64	(0.93)	0.54	(0.85)	0.71	(0.98)
ET participation	0.13	(0.33)	0.13	(0.34)	0.11	(0.31)	0.14	(0.35)
ET units	0.15	(0.55)	0.15	(0.55)	0.12	(0.51)	0.17	(0.58)
IT participation	0.47	(0.50)	0.47	(0.50)	0.44	(0.50)	0.49	(0.50)
IT units	0.46	(0.71)	0.47	(0.73)	0.42	(0.66)	0.51	(0.77)
Student demographics								
Female	0.49	(0.50)	0.50	(0.50)	0.52	(0.50)	0.49	(0.50)
Race/ethnicity								
Black	0.12	(0.33)	0.17	(0.37)	0.20	(0.40)	0.14	(0.35)
Asian	0.09	(0.29)	0.09	(0.29)	0.12	(0.32)	0.08	(0.27)
Hispanic	0.16	(0.37)	0.23	(0.42)	0.22	(0.42)	0.23	(0.42)
White	0.54	(0.50)	0.43	(0.50)	0.40	(0.49)	0.45	(0.50)
Other race	0.06	(0.24)	0.07	(0.25)	0.01	(0.11)	0.10	(0.30)
Family arrangement								
Single parent	0.26	(0.44)	0.40	(0.49)	0.39	(0.49)	0.41	(0.49)
Both biological parents	0.57	(0.49)	0.43	(0.50)	0.42	(0.49)	0.44	(0.50)
Other arrangement	0.15	(0.35)	0.15	(0.36)	0.17	(0.38)	0.14	(0.35)
Academic history/attitudes								
Individualized education plan	0.17	(0.38)	0.23	(0.42)	0.18	(0.38)	0.26	(0.44)
Ninth grade GPA	2.67	(0.91)	2.46	(0.91)	2.37	(0.91)	2.51	(0.91)
Academic units	17.85	(5.63)	16.99	(5.56)	16.52	(5.18)	17.29	(5.77)
Math test score	0.55	(0.17)	0.50	(0.16)	0.47	(0.16)	0.52	(0.16)
Math self-efficacy	5.43	(2.97)	5.20	(2.94)	5.09	(2.81)	5.26	(3.01)
Postse condaiy expectations								
Two years or less	0.10	(0.30)	0.13	(0.34)	0.18	(0.39)	0.09	(0.29)
Four years or more	0.74	(0.44)	0.64	(0.48)	0.61	(0.49)	0.67	(0.47)
School variables								
Percent of minority students	33.71	(29.53)	39.95	(32.08)	44.30	(33.73)	36.80	(30.45)
Percent ELL students	4.59	(8.55)	5.74	(9.82)	5.96	(10.28)	5.59	(9.49)
Urbanicity								
Urban	0.31	(0.46)	0.30	(0.46)	0.37	(0.48)	0.26	(0.44)
Suburban	0.48	(0.50)	0.46	(0.50)	0.45	(0.50)	0.47	(0.50)
Rural	0.21	(0.41)	0.24	(0.43)	0.18	(0.39)	0.27	(0.45)
N	36,700		13,940		5,520		8,420	

Note: All variables binary except the following – GPA (0–4); academic credits (0–53); math score (0.17–0.93); percent minority (0–100); percent ELL (0–76).

academic history variables were sourced from the transcript files. All variables are binary, unless otherwise noted.

Analytic approach

RQ 1 – AS-CTE coursetaking in high school

To address our first research question regarding changes in AS-CTE coursetaking over time between ELS and HSLS students in terms of whether a student enrolled, we estimated the following linear probability model:

$$ASCTE_{ij} = \beta_0 + \beta_1 HSLS_{ij} + \beta_2 X_{ij} + \gamma_j + \varepsilon_{ij}.$$

We chose to use a linear probability model because of the ease in interpreting coefficients, such that the results are identified as percentage increases in the probability of an outcome occurring – participation in AS-CTE in this case. Under our identified model above, the outcome variable $ASCTE_{ij}$ represents AS-CTE enrollment by student i in state j throughout high school. Our variable of interest, $HSLS_{ij}$, indicates whether a student was a member of the HSLS dataset. The coefficient identifies the percent change in likelihood to participate in AS-CTE. X_{ij} is the vector of control variables identified in Table 1. The term γ_j represents the state indicator variable for each state j in our dataset. We chose to explore these relationships using state fixed effects because of the potential for unobserved variation across states relating to policies, implementation, or education initiatives that might have influenced AS-CTE coursetaking (e.g. some states may have been more likely to invest additional resources into the development and rollout of specific AS-CTE programs). Therefore, we may have been falsely estimating any growth or decline in AS-CTE over time. Under this model, we leave one state out as the reference, in order to explore within-state variation between ELS and HSLS cohorts. Finally, ε_{ij} is the error term that includes any unobserved determinants of our identified outcome. This term is estimated with robust standard errors adjusted for high school clustering to account for the nested structure of our data.

To address whether there were changes in AS-CTE the number of units students completed, we also estimated an ordinary least squares (OLS) regression model in which the outcome of interest was unit completion in AS-CTE, as this outcome is a continuous variable. By examining the number of units students are completing, we will be able to determine if students in the HSLS sample were participating more deeply in this CTE work. The coefficient associated with the HSLS indicator gives the average difference in number of AS-CTE units students in the HSLS data took relative to the ELS students.

Note that we repeat the analyses for the ET and IT clusters separately. We employ linear probability models (for participation) and OLS regressions (for unit completion) for each of the analytic methods associated with the additional research questions below. We also repeated these analyses with logistic regression in the case of participation in order to confirm the direction and significance.[1] State fixed effects are included in all of our analyses.

RQ 2 – AS-CTE coursetaking by grade in high school

Based on previous research indicating that the timing of CTE coursework may play an important role in predicting various student outcomes, we also explored whether specific changes in AS-CTE coursetaking over time were more evident in specific grades in high school. We were also interested in whether changes in AS-CTE coursetaking were more prevalent in ET or IT courses. This model is specified as follows:

$$ASCTEclusteryear_{ij} = \beta_0 + \beta_1 HSLS_{ij} + \beta_2 X_{ij} + \gamma_j + \varepsilon_{ij}.$$

The outcome in this model is slightly different than our baseline model from question 1. $ASCTEclusteryear_{ij}$ represents the specific cluster (e.g. ET or IT) and grade (e.g. freshman, sophomore, junior, or senior year) in which participation took place. For example, we individually examined the change in ET participation in freshman year, IT participation in senior year, and so on. This allowed us to more carefully highlight when and in which AS-CTE cluster any changes were taking place.

[1]Logistic regression results are available upon request.

RQ 3 – AS-CTE coursetaking by student sub-group

In addition to the timing of AS-CTE coursetaking, we also explored whether specific subgroups of students changed AS-CTE course taking patterns between ELS and HSLS. Specifically, we were interested in female students, and students with IEPs because of the potential for AS-CTE to have differential relationships for these groups (Gottfried & Plasman, 2018a; Plasman & Gottfried, 2018). To estimate these results, we included an interaction term in our model that indicated the specific relationship between group and dataset membership. This equation is presented below:

$$ASCTE_i = \beta_0 + \beta_1 HSLS_i + \beta_2 Group_i + \beta_3 HSLS * Group_i + \beta_4 X_i + \gamma_j + \varepsilon_i.$$

The coefficient associated with the interaction term $HSLS * Group_{ij}$ (where *Group* identifies membership in female or IEP) is the main variable of interest as it provides us with evidence regarding whether a specific group experienced any additional growth in AS-CTE coursetaking between ELS and HSLS. Our outcome, $ASCTE_{ij}$, is the same as identified in our first research question.

RQ 4 – coursetaking in other CTE fields

Our final question asked how AS-CTE coursetaking changed in relation to other CTE clusters. We explored this relationship in two different ways. First, we identified the ratio of AS-CTE to total CTE as a ratio (i.e. the percentage of CTE that fell into the AS-CTE category). Second, we ran our baseline model looking at each of the following CTE categories as outcomes: agriculture and natural resources, business, communication, health, and manufacturing. The equation is identical to that related to question 1, except that the outcomes were those mentioned here. Additionally, in responding to this question we only looked at the changes in unit completion for each outcome.

Results

AS-CTE courstaking

Our first research question asked whether low-income students in the class of 2013 (HSLS sample) were more likely to participate in AS-CTE coursework and complete more AS-CTE units than low-income students in the class of 2004 (ELS sample). Table 2 presents the findings from our analyses predicting participation in AS-CTE, ET, and IT coursework. In a linear probability model as we have estimated here, a positive coefficient indicates an increase in the probability of participation in our outcome of interest. State fixed effects are included in all our estimations.

In exploring participation as an outcome, several key patterns emerge. First, low-income students in HSLS were more likely to participate generally in AS-CTE than students in ELS. As presented in Model 1, we see that students in the graduating class of 2013 were about 7% more likely to participate in AS-CTE broadly than were students in the class of 2004. When breaking out AS-CTE by the two clusters of which it composed, students in the class of 2013 were significantly more likely to participate in ET coursework. In Model 2, we see that students in the class of 2013 were approximately

Table 2. AS-CTE participation.

	(1)		(2)		(3)	
	Course participation – linear probability model					
	AS-CTE		ET		IT	
	Coef[a]	Std. err[b]	Coef.	Std. err.	Coef.	Std. err.
HSLS	0.07***	(0.02)	0.02*	(0.01)	0.03	(0.02)
Student demographics						
Female	−0.13***	(0.01)	−0.13***	(0.01)	−0.06***	(0.01)
Race/ethnicity						
Black	−0.02	(0.02)	−0.02	(0.01)	−0.01	(0.02)
Asian	0.02	(0.02)	−0.00	(0.01)	0.03	(0.02)
Hispanic	0.03	(0.01)	−0.01	(0.01)	0.03*	(0.01)
Other Race	0.01	(0.02)	0.02	(0.01)	−0.00	(0.02)
Family arrangement						
Single parent	−0.00	(0.01)	−0.01	(0.01)	0.00	(0.01)
Other arrangement	−0.00	(0.01)	−0.01	(0.01)	−0.01	(0.01)
Academic history/attitudes						
Individualized education plan	−0.01	(0.01)	−0.00	(0.01)	−0.01	(0.01)
Ninth grade GPA	−0.00	(0.01)	0.00	(0.00)	−0.00	(0.01)
Academic units	0.01***	(0.00)	−0.00	(0.00)	0.01***	(0.00)
Math test score	0.06	(0.04)	0.08**	(0.03)	−0.00	(0.04)
Math self-efficacy	−0.00	(0.00)	0.00	(0.00)	−0.00	(0.00)
Postsecondary expectations						
Two years or less	0.02	(0.02)	0.01	(0.01)	0.02	(0.02)
Four years or more	0.00	(0.01)	0.01	(0.01)	0.00	(0.01)
School demographics						
Percent of minority students	−0.00	(0.00)	0.00	(0.00)	−0.00	(0.00)
Percent ELL students	−0.00	(0.00)	−0.00	(0.00)	−0.00	(0.00)
Urbanicity						
Urban	0.04*	(0.02)	−0.00	(0.01)	0.04	(0.02)
Rural	0.02	(0.02)	0.00	(0.01)	0.01	(0.02)
F-statistic		14.68		20.17		8.35
N	13,940		13,940		13,940	

[a]Coefficients represent anticipated % increase in probability of outcome occurring per unit increase of identified variable.
[b]Heteroskedasticity robust errors adjusted for school clustering are in parentheses.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

2% more likely to participate in ET courses. However, there were no differences in participation in IT coursework (Model 3).

Table 3 presents the full results predicting the number of units of AS-CTE, ET, and IT. Unlike participation, students in the class of 2013 were completing more units in all three of our areas of interest. Model 1 shows that low-income students in the class of 2013 sample completed 0.11 more units of AS-CTE on average than did low-income students in the class of 2004. When comparing this to the baseline number of credits completed by students in the class of 2004 – an average of 0.55 AS-CTE units – these additional 0.11 units represent about a 20% increase in the number of units completed. Another way of interpreting this result is in viewing the school year as a set of 10 months over which to complete one unit. Therefore, an increase in 0.11 units would translate to approximately one additional month of coursetaking.

When breaking down unit completion across ET (Model 2) and IT (Model 3) courses, there were increases in unit completion across both sub-areas of AS-CTE. Students in the class of 2013 were predicted to exhibit slightly larger increases in IT

Table 3. AS-CTE unit completion.

	(1)		(2) Unit completion		(3)	
	AS-CTE		ET		IT	
	Coef[a]	Std. error[b]	Coef	Std. error	Coef.	Std. error
HSLS	0.11***	(0.03)	0.03*	(0.01)	0.06*	(0.02)
Student demographics						
Female	−0.30***	(0.02)	−0.19***	(0.01)	−0.11***	(0.01)
Race/ethnicity						
Black	−0.04	(0.03)	−0.03*	(0.02)	−0.01	(0.03)
Asian	0.03	(0.04)	−0.03	(0.02)	0.06*	(0.03)
Hispanic	0.02	(0.02)	−0.01	(0.01)	0.03	(0.02)
Other race	−0.02	(0.04)	−0.01	(0.02)	−0.01	(0.03)
Family arrangement						
Single parent	−0.01	(0.02)	−0.02	(0.01)	0.01	(0.01)
Other arrangement	0.00	(0.02)	−0.00	(0.02)	0.01	(0.02)
Academic history/attitudes						
Individualized education plan	−0.01	(0.02)	0.00	(0.02)	−0.01	(0.02)
Ninth grade GPA	0.04**	(0.01)	0.02***	(0.01)	0.02	(0.01)
Academic units	0.02***	(0.00)	0.00	(0.00)	0.02***	(0.00)
Math test score	0.19**	(0.07)	0.13**	(0.04)	0.04	(0.06)
Math self-efficacy	−0.00	(0.00)	0.00	(0.00)	−0.00	(0.00)
Postsecondary expectations						
Two years or less	0.04	(0.03)	0.02	(0.02)	0.03	(0.02)
Four years or more	0.00	(0.02)	0.00	(0.01)	0.00	(0.02)
School demographics						
Percent of minority students	0.00	(0.00)	0.00	(0.00)	0.00	(0.00)
Percent ELL students						
Urbanicity	−0.00	(0.00)	−0.00	(0.00)	−0.00	(0.00)
Urban	0.01	(0.03)	−0.02	(0.01)	0.02	(0.03)
Rural	0.01	(0.03)	−0.01	(0.02)	0.02	(0.03)
F-statistic		26.71		15.38		16.45
N	13,940		13,940		13,940	

[a]Coefficients represent anticipated increase in unit completion per unit increase of identified variable.
[b]Heteroskedasticity robust errors adjusted for school clustering are in parentheses.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

courses – 0.06 units – than ET courses – 0.03 units. While this increase may seem like a small amount, particularly in relation to ET, it is important to keep in mind that the mean number of ET units completed by students in the ELS cohort was only 0.12. Therefore, growth of 0.03 units represents a 25% increase.

AS-CTE coursetaking by grade

Our second research question explored the change in AS-CTE coursetaking in more detail with relation to the timing of coursetaking. The results from these analyses are presented in Table 4. The first three models present participation results, while models four through six present changes in AS-CTE unit completion. In addition to breaking out results by AS-CTE cluster, we also break out results by year of high school. Only the coefficient of interest is presented here for the sake of parsimony.

When exploring changes in participation in AS-CTE, we found that this growth in participation was predominantly related to changes during the freshman year. Students in the class of 2013 were approximately 6% more likely to participate in AS-CTE during their freshman year than students in the class of 2004 (Model 1). When breaking participation

Table 4. AS-CTE unit completion and participation by year.

	Participation[a]						Units[b]					
Freshman year	(1)		(2)		(3)		(4)		(5)		(6)	
	AS-CTE		ET		IT		AS-CTE		ET		IT	
	Coef	Std. err.[c]	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
HSLS	0.06***	(0.02)	0.02***	(0.01)	0.04*	(0.02)	0.08***	(0.01)	0.02***	(0.00)	0.06***	(0.01)
F-statistic		5.62		8.73		2.71		7.24		7.03		5.24
N		13,940		13,940		13,940		13,940		13,940		13,940
	Participation[a]						Units[b]					
Sophomore year	(7)		(8)		(9)		(10)		(11)		(12)	
	AS-CTE		ET		IT		AS-CTE		ET		IT	
	Coef	Std. err.[c]	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
HSLS	−0.00	(0.01)	0.00	(0.01)	−0.00	(0.01)	0.02	(0.01)	0.01	(0.00)	0.02**	(0.01)
F-statistic		7.98		7.83		3.07		9.92		5.67		5.53
N		13,940		13,940		13,940		13,940		13,940		13,940
	Participation[a]						Units[b]					
Junior year	(13)		(14)		(15)		(16)		(17)		(18)	
	AS-CTE		ET		IT		AS-CTE		ET		IT	
	Coef	Std. err.[c]	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
HSLS	−0.00	(0.01)	−0.00	(0.00)	−0.00	(0.01)	−0.00	(0.01)	−0.00	(0.00)	0.00	(0.01)
F–statistic		9.13		9.84		4.73		10.84		6.59		6.79
N		13,940		13,940		13,940		13,940		13,940		13,940
	Participation[a]						Units[b]					
Senior year	(19)		(20)		(21)		(22)		(23)		(24)	
	AS-CTE		ET		IT		AS-CTE		ET		IT	
	Coef	Std. err.[c]	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
HSLS	−0.00	(0.01)	0.01**	(0.00)	−0.00	(0.01)	−0.00	(0.01)	0.01	(0.00)	−0.01	(0.01)
F-statistic		14.47		9.16		5.91		12.90		7.48		9.40
N		13,940		13,940		13,940		13,940		13,940		13,940

[a]Coefficients represent anticipated % increase in probability of outcome occurring per unit increase of identified variable.
[b]Coefficients represent anticipated increase in unit completion per unit of identified variable. [c]Heteroskedasticity robust errors adjusted for school clustering are in parentheses.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

Table 5. AS-CTE unit completion and participation by student group.

	Participation[a]						Units[b]					
	(1) AS-CTE Participation		(2) ET Participation		(3) IT Participation		(4) AS-CTE units		(5) ET units		(6) IT units	
	Coef.	Std. Error[c]	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
HSLS	0.06**	(0.02)	0.03*	(0.01)	0.03	(0.02)	0.14***	(0.03)	0.05*	(0.02)	0.07*	(0.03)
HSLS*Female	0.02	(0.02)	−0.01	(0.01)	0.01	(0.02)	−0.07*	(0.03)	−0.05*	(0.02)	−0.02	(0.03)
F-Statistic		14.02		19.72		7.96		25.73		15.09		15.68
N		13,940		13,940		13,940		13,940		13,940		13,940
	Participation[a]						Units[b]					
	(7) AS-CTE Participation		(8) ET Participation		(9) IT Participation		(10) AS-CTE units		(11) ET units		(12) IT units	
	Coef.	Std. Error[c]	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error	Coef.	Std. Error
HSLS	0.05**	(0.02)	0.02*	(0.01)	0.02	(0.02)	0.10**	(0.03)	0.03*	(0.01)	0.04	(0.03)
HSLS*IEP	0.07**	(0.03)	0.00	(0.02)	0.08**	(0.03)	0.07	(0.05)	−0.03	(0.03)	0.08	(0.04)
F-Statistic		14.47		18.98		8.48		25.59		14.50		15.85
N		13,940		13,940		13,940		13,940		13,940		13,940

[a]Coefficients represent anticipated % increase in probability of outcome occurring per unit increase of identified variable.
[b]Coefficients represent anticipated increase in unit completion per unit of identified variable.
[c]Heteroskedasticity robust errors adjusted for school clustering are in parentheses.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

out by cluster, HSLS students were 2% more likely to participate in ET (Model 2) and 4% more likely to participate in IT (Model 4) during their freshman year compared to those in the previous cohort. Beyond freshman year, there were no consistent patterns.

Similar to participation, differences in unit completion between the class of 2013 and the class of 2004 were also most consistent in freshman year. In AS-CTE broadly speaking, students in the class of 2013 completed on average 0.08 additional units (Model 4). Comparing this to the mean number of AS-CTE units completed by students in the class of 2004, this increase is equivalent to an increase of approximately 15%. ET (Model 5) and IT (Model 6) courses also experienced growth over the two cohorts, with HSLS students expected to complete 0.02 additional units in ET 0.05 units in IT. Again, the patterns were not consistent after freshman year.

AS-CTE coursetaking by student sub-group

In addition to determining if low-income students in the HSLS sample in general were more likely to participate in AS-CTE, we also identified whether specific sub-groups of low-income students were more likely to participate in AS-CTE. We were particularly interested in low-income female students and low-income students with IEPs. The coefficient of interest for our analyses, presented in Table 5, represents the interaction term between HSLS and the identified sub-group. The first three models give the results associated with AS-CTE participation, while models four through six are related to unit completion.

Model 1 indicates that low-income female students in the HSLS sample were not significantly any more or less likely to participate in AS-CTE courses that low-income female students in the ELS cohort. When exploring the interaction between HSLS and students with IEPs, however, we did observe that students with IEPs in the HSLS sample had a higher likelihood of participating in AS-CTE by about 7% compared to low-income students with IEPs in the previous cohort (Model 7). Breaking out AS-CTE into clusters, students with IEPs in the HSLS sample were approximately 8% more likely to participate in IT than were students with IEPs in the ELS sample (Model 9), though they were not more likely to participate in ET courses (Model 8).

When looking at results with regards to unit completion, a different story begins to emerge. First, low-income female students in the HSLS sample were actually predicted to complete approximately 0.07 fewer units in AS-CTE than were female students in the ELS sample (Model 4). Therefore, we see that while female students are participating in AS-CTE at approximately the same rate between cohorts, females in the more recent cohort are taking fewer courses. Thus, while the number of low-income female students participating in AS-CTE did not change over time, the number of units pursued did – a drop, in fact. A similar pattern emerged in the ET cluster. Low-income female students in the HSLS sample were expected to complete approximately 0.05 fewer units than low-income female students in the ELS sample (Model 5).

There were no significant relationships in unit completion with regards to students with IEPs. Again, when also considering participation results, this finding implies that students with IEPs in the HSLS class of 2013 were more likely to participate in AS-CTE, in the aggregate; however, students were not taking more of them on average.

Other CTE field coursetaking

Our final research question asked whether changes in CTE coursetaking by low-income students were limited to AS-CTE, or if there were also evident changes across other CTE clusters. We first looked to see whether there was a change in the percentage of CTE units identified as AS-CTE. We next identified the five most popular CTE categories to see if there changes in participation and unit completion across those categories. These categories were identified based on the percentage of students who participated in them. As has been done in previous research, all business related CTE clusters – business management and administration, business support, and finance – were collapsed into a single category (Plasman et al., 2017). Ultimately, we identified the following five categories: agriculture and natural resources, business, communication, health, and manufacturing. Table 6 presents the results from our analyses.

As above, we first explored the participation patterns in each of our identified CTE categories. First, there was no significant change between the class of 2013 and the class of 2004 in the area of agriculture and natural resources (Model 1). However, low-income students in the HSLS sample were approximately 27% less likely to participate in business CTE courses (Model 2). Likewise, they were about 5% less likely to participate in communication courses (Model 3). Health, on the other hand, was associated with a 3% increase in likelihood of participation by students in the HSLS sample (Model 4). Finally, low-income HSLS students were 14% less likely to participate in manufacturing coursework than low-income ELS students (Model 5). If we consider health to be a STEM-adjacent field, these findings indicate that applied STEM and

Table 6. Participation and unit completion in other CTE categories.

	(1)		(2)		(3)		(4)		(5)		(6)	
	CTE cluster participation[a]											
	Agriculture and nat. res.		Business		Communication		Health		Manufacturing		AS-CTE/total CTE[c]	
	Coef.	Std. Err[b]	Coef.	Std. Err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
HSLS	−0.00	(0.01)	−0.27***	(0.02)	−0.05***	(0.01)	0.03**	(0.01)	−0.14***	(0.01)	0.05***	(0.01)
F-statistic		21.60		22.33		15.19		16.48		24.25		20.13
N		13,940		13,940		13,940		13,940		13,940		13,940

	(7)		(8)		(9)		(10)		(11)	
	CTE cluster units[d]									
	Agriculture and nat. res.		Business		Communication		Health		Manufacturing	
	Coef.	Std. Err[b]	Coef.	Std. Err.	Coef.	Std. err.	Coef.	Std. err.	Coef.	Std. err.
HSLS	−0.04	(0.02)	−0.49***	(0.03)	−0.07***	(0.02)	0.10***	(0.02)	−0.15***	(0.02)
F-statistic		13.78		19.47		16.44		12.09		17.06
N		13,940		13,940		13,940		13,940		13,940

[a]Coefficients represent anticipated % increase in probability of outcome occurring per unit increase of identified variable.
[b]Heteroskedasticity robust errors adjusted for school clustering are in parentheses.
[c]Coefficients represent anticipated increase in proportion of AS-CTE to total CTE units per unit of increase of identified variable.
[d]Coefficients represent anticipated increase in unit completion per unit of identified variable.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

STEM related CTE coursework experienced significant growth over the decade between the class of 2004 and the class of 2013 – with the Perkins reauthorization falling in between – while other CTE coursework saw a fairly sizeable decrease in participation.

We next turn to results related to unit completion. Model 6 in the table presents the percentage of CTE units that fell into the AS-CTE category. As presented here, low-income students in HSLS were expected to increase the share of AS-CTE in relation to total CTE by about 5% as compared to students in the ELS sample. There were also evident changes across each of the other CTE categories. As with participation, there were associated decreases in unit completion in business (Model 8 – 0.49 fewer units for students in the class of 2013), communication (Model 9 – 0.07 fewer units), and manufacturing (Model 11 – 0.15 fewer units). In the case of business, this represents nearly a full semester – the length of a typical CTE course – decrease in units. On the other hand, low-income students in HSLS were predicted to complete approximately 0.10 additional units in the health CTE cluster (Model 10). There was no observed change in the agriculture and natural resources cluster (Model 7). Taking each of these results related to unit completion together, AS-CTE appears to be experiencing a surge in the share of CTE it represents, due to simultaneous growth in AS-CTE unit completion coupled with decreases in many other CTE areas.

Discussion

Federal policy governing CTE in the USA has steadily moved toward promoting math and science skills through participation in technology-based programs. Furthermore, the Perkins Act highlights the importance of encouraging enrollment by special populations of students, including: low-income students, students with disabilities, and female students in nontraditional fields (e.g. AS-CTE). AS-CTE fits the call to promote math and science skills through technology and has also shown potential benefits for students with disabilities – improved high school graduation – and female students – persistence in engineering fields (Gottfried & Plasman, 2018a; Plasman & Gottfried, 2018). Considering these benefits for groups that are traditionally underrepresented in AS-CTE coursework and STEM fields in general, we were interested in exploring whether the most recent authorization of the Perkins Act helped promote coursetaking for these specified groups.

AS-CTE represents a potential means for gaining access to high-wage jobs for many students and has the potential to provide low-income students with a path to the middle class. Therefore, this study provides valuable insight into the work that has been done in an effort to reach these students. By comparing two cohorts of nationally representative secondary students from before and after the authorization of Perkins IV – the graduating class of 2004 (i.e. ELS) and the graduating class of 2013 (i.e. HSLS) – we are able to determine if the policy is moving in the desired direction. We explore this relationship specifically in the area of AS-CTE because of the identified benefits from participation in these courses as well as concerns over a STEM shortage across the nation.

Providing support for the continued funding of CTE programs, we found low-income students in the class of 2013 were significantly more likely to participate in AS-CTE coursework compared to those in the class of 2004. In other words, low-income students in the more recent HSLS cohort had a higher probability of completing at least one AS-CTE course than students in ELS. Additionally, they were completing more units in these AS-CTE courses. HSLS low-income students completed approximately an additional month's worth of AS-CTE coursework than ELS students.

This is not to say that Perkins IV was directly causing this increase in participation and unit completion. It is quite possible that changes in the state of the national economy were driving students to pursue STEM-related training to improve their odds of securing employment (Wright, 2017). Likewise, relaxed pressures from previous No Child Left Behind requirements may have encouraged schools to increase the CTE course offerings. Regardless, the findings in our study suggest that low-income students after the Perkins IV reauthorization in 2006 were more likely to participate in AS-CTE courses and were also completing more units of AS-CTE.

We also examined the individual clusters of IT and ET that compose AS-CTE and the years in which these courses were taken. Evidence points to pathways and outcomes relating to specific CTE clusters (Gottfried & Plasman, 2018a; Plasman et al., 2017), as well as the importance of examining when courses were completed in high school (Gottfried & Plasman, 2018b). With regard to clusters, we found an increase in participation only in the ET cluster over the full four years of high school. However, low-income HSLS students did exhibit greater participation in both ET and IT clusters during the freshman year. There was very little change in later years in high school, though low-income students in the class of 2013 were slightly more likely to participate in ET during their senior year.

A somewhat similar pattern emerged in exploring unit completion by cluster and year. In the area of ET, HSLS low-income students were predicted to complete more units. They were also predicted to complete more IT units. Again, these changes were almost solely limited to increases during the freshman year. However, low-income students in the class of 2013 were predicted to complete more units during sophomore year than were low-income students in the class of 2004.

We next turned to an exploration of coursetaking patterns for low-income female students and low-income students with disabilities because of the traditional underrepresentation of these groups in STEM areas (Gottfried & Plasman, 2018a; Plasman & Gottfried, 2018). In the cross-cohort analysis of female students, we found students in the class of 2013 were neither more nor less likely to participate in AS-CTE in general, nor were there differences in examining the individual clusters of ET and IT. However, these same students were predicted to complete fewer units in AS-CTE in general, and ET more specifically, than were low-income female students in the class of 2004. This change may be due to predicted growth in fields in which women have been more traditionally employed, such as healthcare, that do not require extensive postsecondary education (Bureau of Labor Statistics, 2016, 2017).

A different story presented itself in examining low-income students with disabilities. First, this group of HSLS students was more likely to participate in AS-CTE broadly, as well as in IT coursework. However, there was no difference in ET, which is the opposite of the full low-income sample. A potential explanation may relate to the idea that ET courses may still present some more theoretical aspects to learning, while IT coursework tends to be applied in practice, which benefits the performance of students with disabilities (Brigham et al., 2011; Moon et al., 2012). While low-income students with disabilities in the class of 2013 were more likely to participate in AS-CTE, they were no more or less likely to complete additional units. This indicates that this group of students was more likely to sample AS-CTE coursework, but they were not necessarily going into greater depth in the AS-CTE field of study.

Perkins IV specifically called for a focus on technology related programs that helped build academic math and science skills. To identify whether growth was focused in these math and science related CTE areas (i.e. AS-CTE), we also looked at whether there were changes in other CTE areas of study. Our analyses in this area supported the idea that states may have been changing the focus of their CTE programs to emphasize AS-CTE. In three of our five identified CTE categories – business, manufacturing, and communication – there was a significant decrease in the probability of participation by students in the class of 2013. Health, on the other hand, was home to a significant increase in participation. While health is not necessarily identified as a STEM field, careers in the health field do require substantial math and science skills and are thus considered STEM adjacent by the Bureau of Labor Statistics and Jones (2014). There was no change evident in the agriculture and natural resources cluster. An identical pattern was evident in unit completion across the HSLS and ELS cohorts: business, manufacturing, and communications experienced predicted decreases in HSLS, health experienced a predicted increase in HSLS, and agriculture and natural resources remained stagnant. Our conclusion that the focus of CTE programing was moving toward more STEM related programing was further borne out by examining the ratio of AS-CTE units to total CTE units completed (i.e. the percentage of CTE that fell into AS-CTE) by students throughout high school. We found low-income students in the class of 2013 were predicted to have a significantly higher percentage of CTE fall into the AS-CTE category than low-income students in the class of 2004.

Implications

There are several implications for policy and practice that arise from these findings. First, the findings provide evidence overall that low-income students in the graduating class of 2013 had a higher probability of enrolling in AS-CTE and were expected to complete more course units. These results suggest that national efforts to improve CTE coursetaking – particularly in areas that promote math and science skills – by special populations of students appear to be finding some footing. This result aligns with previous work done by Lee (2014) presenting evidence that low-income students with disabilities were more likely to enroll in STEM majors in four-year and vocational and technical institutions compared to their higher income peers. With the recent reauthorization of the Perkins Act, these results provide support for the continued funding of career and technical education at the secondary level.

Second, while we did find positive evidence that low-income students after the reauthorization of Perkins IV exhibited increased AS-CTE coursetaking patterns across high school, we would press policymakers to consider a more nuanced view of this coursetaking as well. Our study found that a vast majority of AS-CTE coursetaking changes occurred in the freshman year. With recent evidence that it CTE later in high school has additional benefit in regard to student outcomes (i.e. high school graduation), finding a means to promote persistence of CTE later in high school should be taken into consideration. Around the country, individual states are implementing policies to encourage additional AS-CTE coursetaking throughout high school. For example, Wisconsin now allows students to earn math and science credits through CTE coursework. In California, many students enroll in career pathways that begin in freshman or sophomore year and progress through senior year. Federal policy could look to reward those states that encourage CTE coursetaking later in high school.

Third, we would also urge policymakers to consider whether federal policies are pushing hard enough to encourage and grow participation of special populations of students. The positive sign is that low-income students have appeared to increase AS-CTE coursetaking as measured by participation and unit completion. However, specific subgroups of low-income students do not experience similar AS-CTE growth. For instance, low-income students with disabilities did exhibit higher rates of participation, but they were not expected to complete more units in AS-CTE in the more recent cohort. Low-income female students in the graduating class of 2013, on the other hand, were not expected to participate in AS-CTE at a higher rate and were actually expected to complete fewer AS-CTE units than this same group of students in the class of 2004. Careers related to AS-CTE coursetaking offer high wages, and federal policymakers should explore including incentives for states to promote overall interest and skill growth in AS-CTE for all students.

Finally, it is certainly encouraging to find evidence of growth in AS-CTE coursetaking by low-income students, and we applaud efforts to engage these students in AS-CTE coursework. However, it is important to keep in mind the other CTE clusters as well. Our study pointed out that the growth of AS-CTE coursetaking was not necessarily paralleled by growth in other CTE areas. One cluster in particular – manufacturing – is worth discussing more closely. A recent report by Deloitte and the Manufacturing Institute et al. (2015) identified a projected shortage of nearly 2 million employees in the manufacturing industry over the next decade. As the United States continues to rebuild after the Great Recession, economic growth in the manufacturing sector looks to play an important role (National Association of Manufacturers, 2017). Considering the role of technology in current manufacturing endeavors, future versions of the Perkins Act may want to highlight this CTE cluster specifically as an area to improve participation.

Continued funding of career and technical education across all the clusters in an effort to create employment opportunities for all workers should be a national priority (US Equal Employment Opportunity Commission, 2017). Recommendations to address these labor market gaps can all be addressed through educational efforts (National Association of Manufacturers, 2017; US Equal Employment Opportunity Commission, 2017). First, school districts and other regional occupation centers can work not just with one group of local employers, but with an entire group in an effort to best align interests and needs. These partnerships should work together to help dispel some of the stigma associated with participation in CTE in general. Second, the training programs and sequences should be modeled with input from both the education sector and the private sector, and these programs should begin earlier in the education process. Apprenticeships and earned industry-recognized credentials represent two potential forms these programs might take. Additionally, these programs should look to recruit from groups that are traditionally underrepresented in trade related careers (i.e. minority students, female students, students with disabilities). Finally, identified programs should be focused on regional needs. Across each of these recommendations is a strong emphasis on partnerships between employers and educational groups. The recently authorized Perkins V does encourage these partnerships, but a more detailed description of potential partnership activities (i.e. internships, apprenticeships, industry recognized credentialing) may help states and districts see options more clearly.

Limitations and future research

There are a few limitations to consider when interpreting these findings. First, these results do not indicate causality. Based on the data we have available, we cannot say for certain that the changes introduced through the Perkins IV reauthorization were the absolute reason for any observed changes in coursetaking patterns by low-income students. We attempt to control for as much observed (through a wide array of control variables) and unobserved biases (through state fixed effects) as possible, but causality cannot be claimed. While there does not currently exist a single continuous national dataset over time, these datasets do exist at the state level in most states. Future research could utilize state-level data to more closely observe the impact of the Perkins reauthorization immediately before and after the changes.

Another potential limitation is through the identification of low-income students. This is a product of the data we had available for analysis. Families were not asked to identify their exact income, but instead identified a bin into which the income fell. Due to this categorical identification, it is possible we did not identify every student who fit our definition of low-income.

A final point to consider is that while there does appear to be a relationship between the 2006 reauthorization and changes in coursetaking patterns for low-income students, there are many unanswered questions. Considering the benefits of participating in AS-CTE, there are many avenues for future research to pursue, with a specific focus on low-income students. Does participation in AS-CTE increase the chances of graduation for low-income students? Were there differences in STEM participation in postsecondary education for low-income students related to the Perkins 2006 reauthorization? Finally, did participation in AS-CTE by low-income students before and after the Perkins 2006 reauthorization have different impacts on later employment outcomes? Answers to these questions will help policymakers and practitioners identify successful ways to help encourage low-income students to study in areas of high demand, while also serving to set the stage for future research evaluating the effects of the policy changes associated with the 2018 reauthorization of the Perkins Act.

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