Early College, Continued Success:

Longer-Term Impact of Early College High Schools

SEPTEMBER 2019

Mengli Song | Kristina L. Zeiser

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1000 Thomas Jefferson Street NW
Washington, DC 20007-3835
202.403.5000

www.air.org

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Executive Summary

About the Study

Building on a previous randomized experiment of the impact of Early Colleges (ECs) (Berger et al., 2013), this follow-up study assessed longer-term impacts of ECs on students' postsecondary outcomes 6 years after expected high school graduation. It also explored the extent to which students' high school experiences mediate EC impacts. Specifically, this study addressed three research questions:

1. Did EC students have better postsecondary outcomes (i.e., college enrollment and degree attainment) than control students?
2. Did the impacts of ECs vary by student background characteristics (i.e., gender, race/ethnicity, low-income status, and prior mathematics and English language arts [ELA] achievement)?
3. Were the impacts of ECs mediated by students' high school experiences (i.e., college credit accrual during high school, instructional rigor, college-going culture, and student supports)?

To answer these questions for the follow-up study, we analyzed 4 more years of postsecondary outcome data from the StudentTracker Service at the National Student Clearinghouse for students participating in the EC admission lotteries that were the basis of the previous impact study. We also analyzed data on student background characteristics from administrative records and data on high school experiences from a student survey administered in the previous impact study 5 or 6 years after students entered the ninth grade.

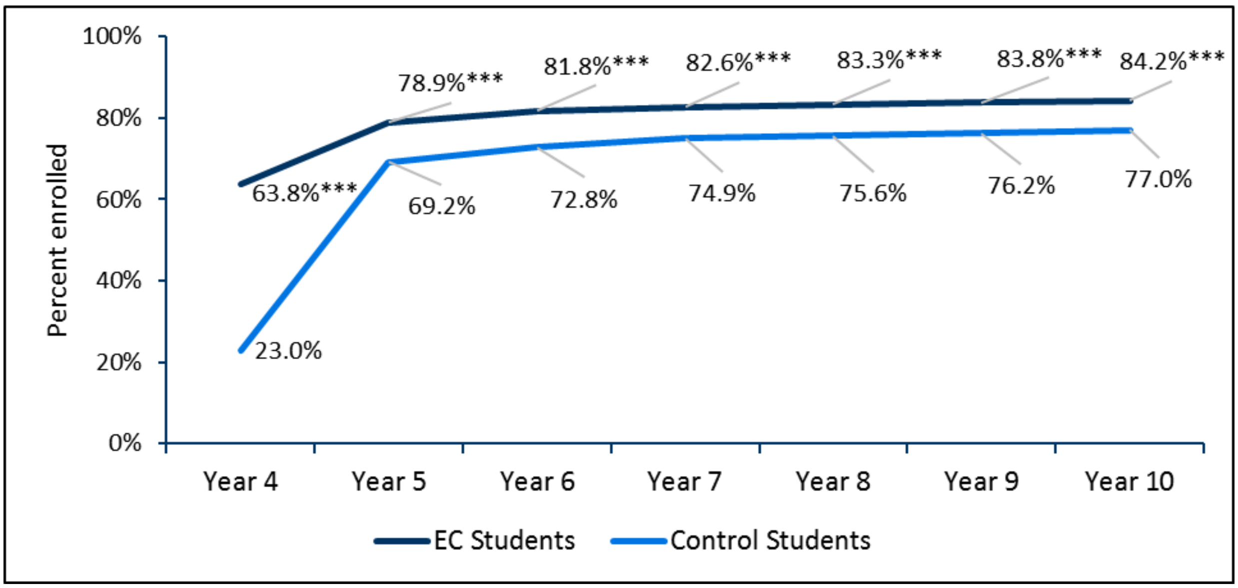
The sample for both the original impact study and the follow-up study included 10 ECs that (1) enrolled students in Grades 9–12, (2) had high school graduates by 2011, (3) used lotteries in their admission processes for at least one of three incoming student cohorts (i.e., students who entered ninth grade in 2005–06, 2006–07, or 2007–08), (4) retained the lottery records, and (5) implemented the EC as a whole-school program. Eight of these ECs partnered with 2-year colleges, and two partnered with 4-year colleges. The main impact analysis sample included 2,458 students in total, 1,044 of whom won the EC lottery (i.e., EC students) and 1,414 of whom did not win the EC lottery (i.e., control students). Study participants were followed from the year they entered Grade 9 (i.e., Year 1) to 6 years after expected high school graduation (i.e., Year 10). The mediating role of high school experiences was examined within eight of the 10 ECs that participated in the student survey administered in the previous impact study, with 1,424 students in total (771 EC students and 653 control students).

Key Study Findings

Impact on College Enrollment

- **EC students were significantly more likely than control students to enroll in college each year between the fourth year of high school and 6 years after expected high school graduation (i.e., Year 10).** Within 6 years after expected high school graduation, 84.2% of EC students had enrolled in college, compared with 77.0% of control students (see Exhibit ES.1).

Exhibit ES.1. Percentage of Students Who Enrolled in Any Colleges Between Year 4 and Year 10, by Study Group



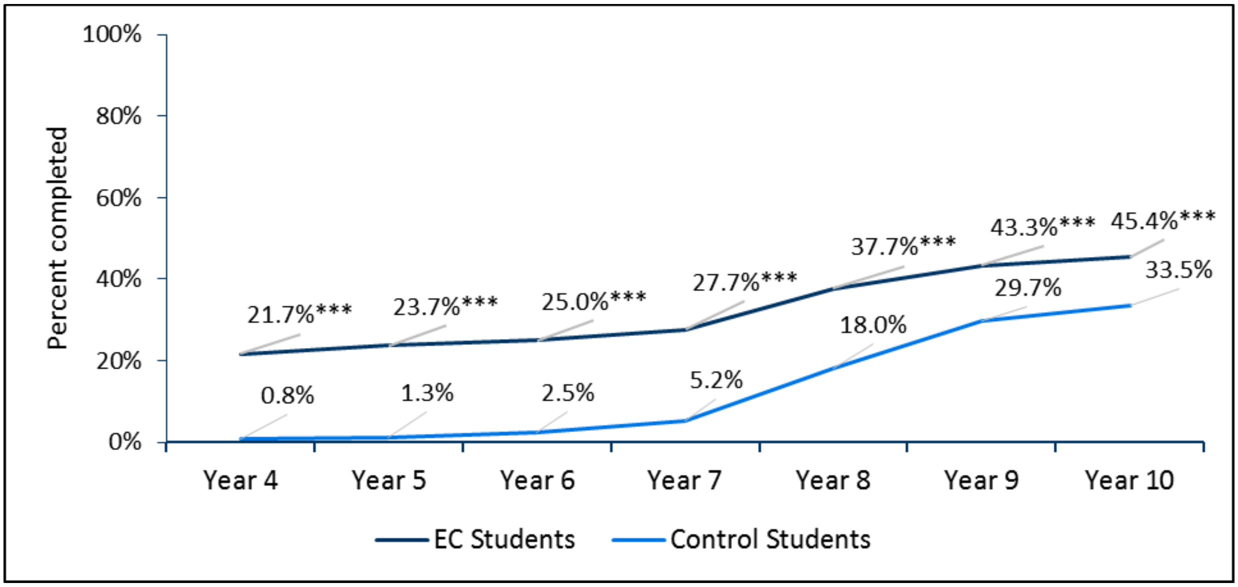
Notes. N = 2,458 (1,044 EC, 1,414 control). The percentages for EC students are unadjusted percentages; the percentages for control students were computed based on the unadjusted percentages for EC students and estimated EC effects.
Year x, x = 4~10, refers to x years after starting high school.
*** $p < .001$.

- **EC students were significantly more likely than control students to enroll in 2-year colleges each year between the fourth year of high school and 6 years after expected high school graduation.** By Year 10, 65.8% of EC students had enrolled in 2-year colleges, compared with 46.8% of control students.
- **EC students and control students were similarly likely to enroll in 4-year colleges and selective 4-year colleges over time.** We did not observe a significant difference in enrollment in 4-year colleges after Year 6.

Impact on Degree Completion

- **EC students were more likely than control students to complete a postsecondary degree each year between the fourth year of high school and 6 years after expected high school graduation.** By Year 10, 45.4% of EC student and 33.5% of control students had completed a certificate, associate's degree, or a bachelor's degree (see Exhibit ES.2).

Exhibit ES.2. Percentage of Students Who Completed Any Postsecondary Degree Between Year 4 and Year 10, by Study Group



Notes. N = 2,458 (1,044 EC, 1,414 control). The percentages for EC students are unadjusted percentages; the percentages for control students were computed based on the unadjusted percentages for EC students and estimated EC effects.
Year x, x = 4~10, refers to x years after starting high school.
*** $p < .001$.

- **EC students were more likely than control students to complete an associate's degree or certificate each year between the fourth year of high school and six years after expected high school graduation.** By Year 10, 29.3% of EC student and 11.1% of control students had completed an associate's degree or certificate.
- **EC students were more likely than control students to complete a bachelor's degree each year between the second and sixth years after expected high school graduation.** By Year 10, 30.1% of EC student and 24.9% of control students had completed a bachelor's degree.

Differential EC Impact

- **EC impacts on college enrollment and degree completion outcomes were similar for students with different family background characteristics.** EC impacts on college enrollment and degree completion outcomes did not differ significantly by gender, race/ethnicity, or eligibility for free or reduced-price lunch.

- **EC impacts on some postsecondary outcomes were stronger for students with higher levels of Grade 8 achievement.** EC impacts on enrollment in 2-year colleges and completion of an associate's degree or certificate within 6 years after expected high school graduation (i.e., by Year 10) were stronger for students with higher levels of Grade 8 achievement. EC impacts on enrollment in 4-year colleges and bachelor's degree completion did not significantly differ by Grade 8 achievement.

The Mediating Role of High School Experiences

- **High school experiences significantly explained the EC impact on enrollment in any type of institution.** High school experiences, as measured by instructional rigor, college-going culture, and student supports, explained approximately 30% the EC impact on enrollment in any type of institution within 6 years after expected high school graduation (i.e., by Year 10). These high school experience measures did not explain the EC impact on enrollment in 2-year colleges.
- **College credit accrual during high school was the strongest mediator for degree completion outcomes, particularly bachelor's degree completion.** Completion of college credits during high school explained approximately 87% of the EC impact on bachelor's degree completion within 6 years after expected high school graduation (i.e., by Year 10).

Summing Up

Adding to the positive findings about the EC impacts on students' high school graduation and postsecondary outcomes from the original impact study, this follow-up study generated strong evidence for the longer-term impacts of ECs on students' postsecondary outcomes. We found that EC students were more likely to enroll in and graduate from 2-year colleges, which may partly be because most of the ECs in our study were partnered with 2-year colleges. While EC students were no more likely than their peers to enroll in 4-year colleges, they were more likely to complete a bachelor's degree and did so earlier in their academic careers. These positive impacts were similarly observed for students from different family backgrounds.

Because EC students were more likely to complete college degrees earlier than their peers, we anticipate positive long-term EC impacts on students' workforce and financial outcomes. While more research is needed to explore the EC impacts on later-life outcomes, the accelerated timeline of degree attainment for EC students combined with the fact that college credits earned at ECs come at little or no cost to them suggest that EC students may accrue less educational debt in their lives. Moreover, as EC students are likely to enter the workforce sooner, we expect that they will have higher lifetime earnings compared with their peers.

Where the mechanisms of EC impacts are concerned, we found that students' high school experiences explained EC impact on overall college enrollment, but they did not explain the EC impact on enrollment in 2-year colleges. This is likely because most EC students enrolled in partnering 2-year colleges while in high school, and their high school experiences were more likely to affect their later outcomes than their outcomes during high school. However, accumulation of college credits during high school explained most of the EC impact on bachelor's degree completion, even though the credits were earned at a 2-year college for the majority of students. This finding speaks to the important role that 2-year colleges can play in the academic trajectories of high school students, when the integration of college coursework into the high school curriculum is intentional and coheres to specific degree-attainment pathways.

Introduction

There is substantial evidence that a postsecondary degree or credential prepares students for successful entry into the workforce. Bachelor's degree holders earn more over a lifetime than individuals with only a high school diploma (Carnevale, Rose, & Cheah, 2011), and college degree earners fared better in the recent American recession than adults with only a high school diploma (Grusky, Bird, Rodriguez, & Wimer, 2013). Moreover, workforce projections consistently predict that the lion's share of future jobs will require a postsecondary degree (Carnevale et al., 2011).

During the past decade, a growing body of research evidence has emerged noting the promise of dual enrollment as an effective way to promote postsecondary access and success. While the implementation of dual enrollment programs varies across schools and may be dictated by state policies, dual enrollment is generally defined as students' participation in college-level courses that count for credit at both the secondary and postsecondary levels. A recent evidence review conducted by the What Works Clearinghouse (WWC, 2017a) concluded that dual enrollment programs had positive effects on high school achievement, high school graduation, credit accumulation, college enrollment, and degree completion outcomes. While the concept of dual enrollment has been around for several decades, it is perhaps due to the evidence of the effectiveness of these programs that there continues to be a push at both the state and federal levels to support partnerships between high schools and postsecondary institutions to provide students with the opportunity to earn college credits during high school (Achieve & Jobs for the Future, 2015; Zinth, 2016).

One type of dual enrollment program that has received much attention and has been expanding rapidly across the nation is Early Colleges (ECs). ECs were originally created as part of the Early College High School Initiative (ECHSI) established in 2002 by the Bill & Melinda Gates Foundation, along with the Carnegie Corporation of New York, the Ford Foundation, and the W.K. Kellogg Foundation. The explicit goal of the initiative was to increase the opportunity for students who are disadvantaged to earn a postsecondary credential. To achieve this goal, ECs partner with colleges and universities to offer students an opportunity to earn an associate's degree or up to 2 years of college credits toward a bachelor's degree during high school at no or low cost to their families.[1] ECs also provide a rigorous and supportive high school environment to help students navigate and succeed in college coursework. More specifically, the ECHSI was guided by the following five core principles:

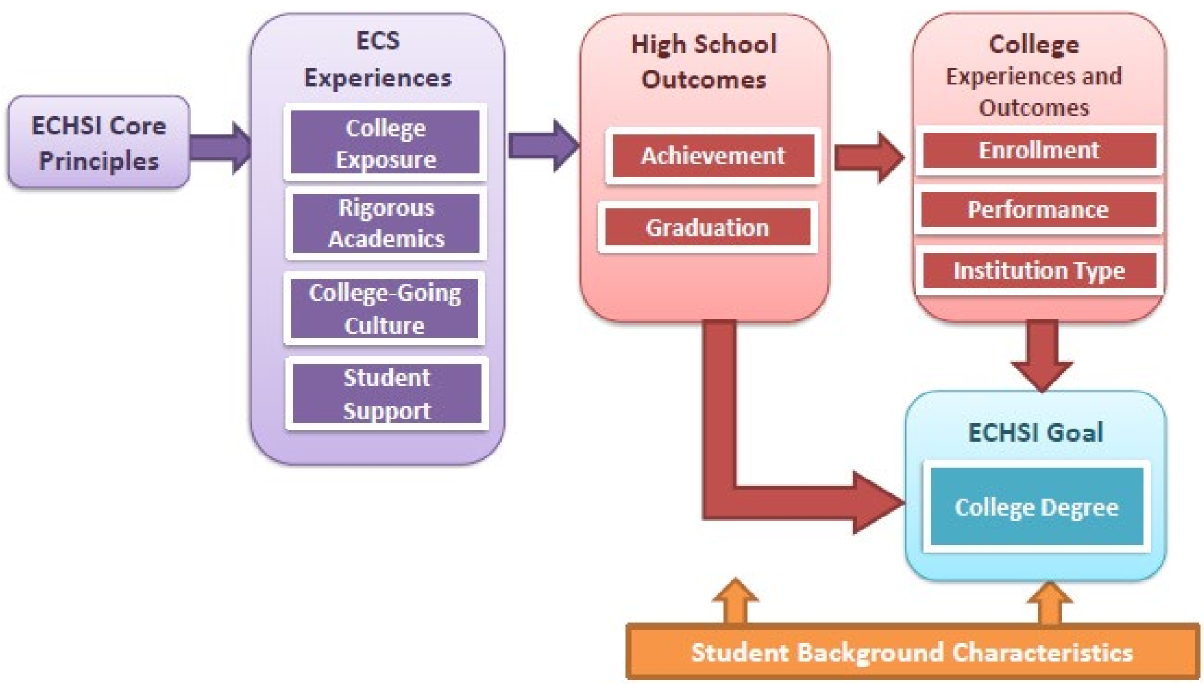
---

[1] ECs employ a variety of approaches to cover students' tuition costs, including tuition payments from the state or district or a college's decision to waive tuition for EC students. Funding availability and local/state policy contexts, however, require that students in some states absorb some or all of this expense (Berger et al., 2009).

1. ECs are committed to serving students underrepresented in higher education.
2. ECs are created and sustained by a local education agency, a higher education institution, and the community, all of whom are jointly accountable for student success.
3. ECs and their higher education partners and community jointly develop an integrated academic program so all students earn one to two years of transferable college credit leading to college completion.
4. ECs engage all students in a comprehensive support system that develops academic and social skills as well as the behaviors and conditions necessary for college completion.
5. ECs and their higher education and community partners work with intermediaries to create conditions and advocate for supportive policies that advance the Early College movement (Jobs for the Future, 2008, p. 2).

The underlying assumption of the ECHSI is that engaging students who are underrepresented in a rigorous high school curriculum tied to the incentive of earning college credit (with reduced financial burden) will increase their access to and success in postsecondary education. Exhibit 1 illustrates the ECHSI theory of change.

Exhibit 1. ECHSI Theory of Change



Between 2010 and 2013, the American Institutes for Research (AIR) conducted an impact evaluation of ECs based on a natural experiment, capitalizing on retrospective admission lotteries that occurred between 2005–06 and 2007–08 (Berger et al., 2013; Berger, Turk-Bicakci, Garet, Knudson, & Hoshen, 2014; Haxton et al., 2016). Among the lottery participants, those who won the lottery and were offered admission were considered treatment students; those who did not win the lottery were considered control students. By means of lottery-based random assignment, any observed outcome differences between the treatment and control students could be attributed exclusively to whether they were offered admission to an EC. The study found that being offered admission to an EC had positive impacts on both college enrollment and degree attainment 2–4 years after expected high school graduation.

This report presents the findings from a follow-up study designed to assess the longer-term impacts of ECs by extending the previous AIR study with 4 more years of student outcome data. Focusing on the impacts of ECs on students' postsecondary outcomes 6 years after expected high school graduation, the follow-up study addressed the following research questions (RQs):

- RQ1: Did EC students have better postsecondary outcomes (i.e., college enrollment and degree attainment) than control students?
- RQ2: Did the impacts of ECs vary by student background characteristics (i.e., gender, race/ethnicity, low-income status, and prior mathematics and English language arts [ELA] achievement)?

In addition to the overall impact (RQ1) and potential differential impact (RQ2) of ECs, this follow-up study also explored the role of students' high school experiences as potential mediators of EC impact, which had not been examined in prior research and which may provide useful insights into the "black box" of ECs. The mediation analyses addressed the following RQ:

- RQ3: Were the impacts of ECs mediated by students' high school experiences (i.e., college credit accrual during high school, instructional rigor, college-going culture, and student supports)?

Before presenting detailed findings for each RQ, we provide a brief review of relevant literature and a description of the methods that we used to address the RQs.

Literature Review

A variety of instructional practices and programs aim to improve students' college and career readiness through "accelerated learning," or programs that offer high school students exposure to college-level instruction (Hodara & Pierson, 2018). One of the most prevalent programs for accelerating students' learning is dual enrollment, which involves students' participation in college-level coursework during high school, allowing students to meet high school and college course requirements simultaneously. ECs are a type of dual enrollment program where

(1) all students within the high school are expected to take college-level courses and (2) students follow a prescribed curriculum that facilitates the accrual of 2 years of college credit, and in some cases the completion of an associate's degree, by the time students graduate from high school.

Qualitative studies of dual enrollment and ECs have found that these opportunities influence the creation of an educational identity and provide supportive and caring relationships between students and teachers, particularly for students who are traditionally underserved in higher education (Beall, 2016; Kanuika & Vickers, 2010; Pitchford-Nicholas, 2015; Thompson & Onganga, 2011; Wolk, 2005). ECs may improve the "clarity of the college-student role," by providing students with a more concrete vision of who is able to succeed in college and which skills are required, allowing students to identify themselves as college ready (Lile, Ottusch, Jones, & Richards, 2018; Newton, 2008; Newton & Vogt, 2008). Rosenbaum and Becker (2011) similarly highlighted the importance of motivating students by creating educational identities and providing frequent opportunities to identify academic strengths and receive the supports they need to succeed. Therefore, as illustrated in the ECHSI theory of change, dual enrollment and EC programs have the potential to positively influence student outcomes by providing students with opportunities to interact with college staff and other college students, exposing them to a rigorous curriculum and an environment where all students are expected to attend college, and making sure they receive the support they need to succeed.

Below, we provide a summary of the research on the impact of dual enrollment programs and ECs on students' secondary and postsecondary outcomes.

Research on Dual Enrollment

Positive effects of dual enrollment programs on student outcomes have been observed in a range of research studies, from correlational research (Karp, Calcagno, Hughes, Dong, & Bailey, 2007; Swanson, 2008) to quasi-experimental studies (An, 2013a; Blankenberger, Lichtenberger, & Witt, 2017; Giani, Alexander, & Reyes, 2014; Miller et al., 2018; Speroni, 2011; Struhl & Vargas, 2012). While some of these studies focused on specific states (e.g., Texas, North Carolina, Indiana) in which education policy requires or facilitates partnerships between high schools and postsecondary institutions (Edmunds et al., 2017; Indiana Commission for Higher Education, 2016; Miller et al., 2018; Struhl & Vargas, 2012), other studies found similarly positive effects of dual enrollment using nationally representative samples of students (An, 2013a; Swanson, 2008). Overall, evidence of the academic benefits associated with dual enrollment has been consistent across study designs, study sites, and types of dual-enrollment programs.

Two seminal correlational studies show that students who took college classes during high school had higher high school grade point averages; were more likely to receive high school diplomas, enroll in college, enroll in college full time, and persist in college; and earned more college credits after high school graduation than students without college experience during high school (Karp et al., 2007; Swanson, 2008). Building off this work, more recent research using quasi-experimental methods found that dual enrollment participation increased the probabilities of college attendance and degree completion (An, 2013a; Struhl & Vargas, 2012).

Research also demonstrates positive relationships between dual enrollment and postsecondary outcomes for students who are traditionally underrepresented in college. For example, dual enrollment was found to be positively associated with college enrollment, grade point average, and degree completion for low-income students and lower-achieving students (An, 2013b; Community College Research Center, 2012). In addition, a study on the Concurrent Course Initiative in California, a career-focused dual enrollment program targeting students traditionally underrepresented in college, found that program participants had higher rates of high school graduation, college enrollment, and college persistence; accumulated more college credits; and required less remediation than nonparticipants (Hughes, Rodriguez, Edwards, & Belfield, 2012; Rodriguez, Hughes, & Belfield, 2012). While some studies found that the effects of dual enrollment are similar for students from different socioeconomic backgrounds (e.g., An, 2013a), one study conducted in Illinois found that the positive effects of dual enrollment on postsecondary enrollment and degree completion outcomes were smaller for minority students and low socioeconomic status students than the average effects observed within the state (Taylor, 2015), suggesting that dual credit programs may need to provide extra support to students who are traditionally underserved in higher education in order to provide similar benefits.

In addition, some research found mixed effects of dual enrollment programs for lower-achieving students: while lower-achieving students participating in dual enrollment programs may be more likely to enroll in college after high school than their peers that do not participate in dual enrollment (Cowan & Goldhaber, 2015; Karp et al., 2007), the rigor of dual enrollment may also be associated with increased incidence of dropout for lower-achieving students (Cowan & Goldhaber, 2015). These findings suggest that the implementation of dual enrollment in the absence of the schoolwide focus on college readiness and individually tailored supports for struggling students, such as those exhibited by ECs, may have unintended negative consequences for traditionally underserved students.

Research on ECs

Since 2002, more than 280 ECs have opened nationwide as part of the ECHSI, serving more than 80,000 students in 31 states and the District of Columbia (Webb, 2014). The number of ECs outside of the ECHSI also has continued to increase across the country, as a growing body of research evidence has emerged noting the promise of ECs as an effective way to promote postsecondary access and success. The most comprehensive study of ECs to date is a 6-year national evaluation of ECHSI conducted by Berger et al. (2009), which collected data on all 157 ECs open nationwide as of fall 2007. The evaluation concluded that EC students performed better than students in other high schools located in the same district. It found, for example, that EC students outperformed their peers in the same district by 7 percentage points on average in terms of proficiency rate on state assessments in both English language arts and mathematics. It also estimated (based on progression rates) that 66% of the students who started at an EC in ninth grade would graduate on time, which was 14 percentage points higher than the estimated graduation rate for other high schools in the local districts.

Prior research also shows that EC students performed favorably compared with national figures. Drawing on data from a representative sample of 100 ECs, a 2014 report released by Jobs for the Future, for example, reveals that EC students were "far more likely to graduate high school"—90% of EC students received a high school diploma vs. 78% of students nationally—despite the fact that ECs serve primarily low-income students and students of color (Webb, 2014, p. 10). The report also shows that EC students were more likely to earn college credits in high school (94% of EC students vs. less than 10% nationally), more likely to complete a college degree by high school graduation (30% of EC students vs. very few students nationally), more likely to enroll in college immediately after high school (71% of EC students vs. 54% of low-income graduates nationally), and more likely to return to college for a second year (86% of EC graduates who enrolled in college vs. 72% of college students nationally).

Most of the existing studies of ECs, however, are descriptive or qualitative in nature and do not warrant causal conclusions about the impact of ECs. One exception is a study that used propensity score matching to assess the EC impact on students' college preparedness in mathematics and science by comparing students attending 33 ECs in North Carolina with similar students attending other high schools in the same districts (Miller & Corritore, 2013). The study found that attending an EC had positive effects on both students' progression through the mathematics pipeline (which consisted of three college-preparatory courses) and their mathematics performance, but nil to negative effects on students' science pipeline progression and no effect on their science performance. Also relying on propensity score matching, a more recent study examined the performance of students at all 70 of the ECs in North Carolina relative to a matched sample of students who attended the same middle school but did not attend the EC during high school (Lauen, Fuller, Barrett, & Janda, 2017). This study found significantly better outcomes for EC students in both high school and college, including lower ninth-grade retention rates, higher test scores, fewer absences, higher graduation rates, higher rates of enrollment at 4-year state colleges, and higher rates of completing an associate's degree within 2 or 3 years of high school completion.

To date, the most rigorous evidence on the impact of ECs came from two natural experiments based on admission lotteries. One is the AIR study mentioned earlier (Berger et al., 2013, 2014; Haxton et al., 2016) that is the basis of the follow-up study presented in this report. The other is a study conducted by the SERVE Center at the University of North Carolina at Greensboro (Edmunds et al., 2012, 2017; Edmunds, Willse, Arshavsky, & Dallas, 2013). Both studies found positive impacts of ECs on a variety of student outcomes both during and after high school.

Similar to the AIR study that is based on admission lotteries taking place in 10 sites, the SERVE Center study is based on admissions lotteries taking place in 12 sites. It found that EC students were more likely to be "on track for college" than control students, and that ninth-grade EC students were more likely than control students to take core college preparatory courses and succeed (Edmunds et al., 2012). The study also found that EC students had higher attendance rates, lower suspension rates, and higher levels of engagement than control students (Edmunds et al., 2013). The most recent report from the SERVE study further shows that EC students accrued significantly more college credits while in high school (21.6 vs. 2.8 credits), and graduated from high school (85.4% vs. 81.4%), enrolled in postsecondary institutions (89.9% vs. 74.3%), and received postsecondary credentials (30.1% vs. 4.2%) at higher rates than control students within 6 years of starting high school (Edmunds et al., 2017).

Overall, the available research evidence on ECs accumulated over the past decade is quite encouraging. Nevertheless, the evidence base for the EC impact on student outcomes is still understandably thin, given the relatively short history of ECs. Moreover, none of the prior studies have examined the EC impact on longer-term student outcomes beyond 2 years after expected high school graduation. By extending the previous AIR EC impact study with 4 more years of postsecondary data, the follow-up study presented in this report represents a significant addition to the existing evidence base on the impact of ECs on longer-term student outcomes.

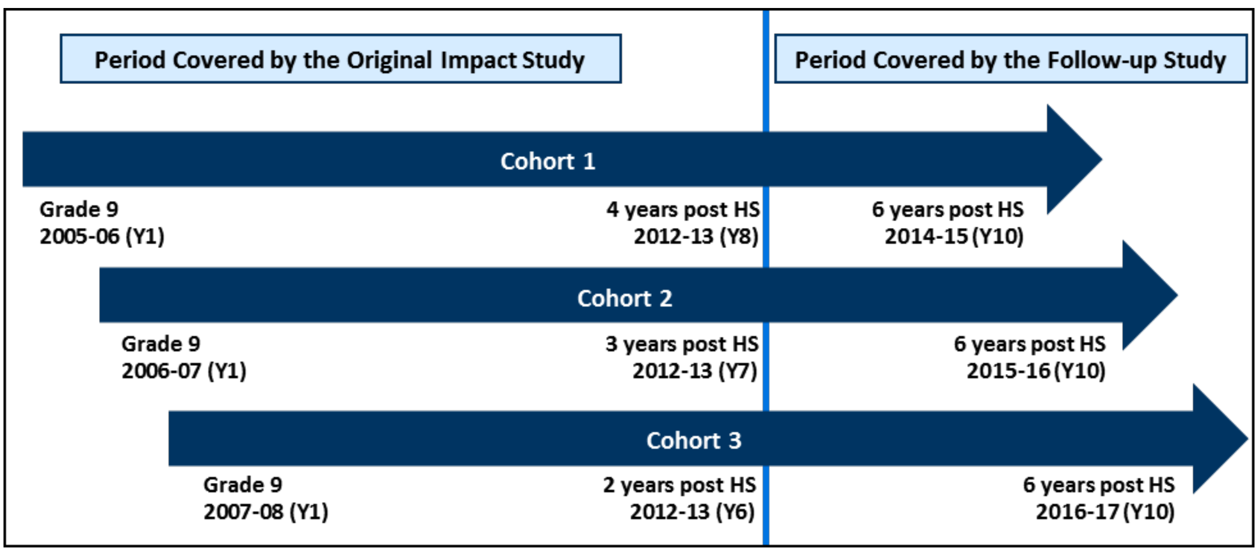
Methods

Sample

The original impact study of the ECHSI (Berger et al., 2013) that is the basis for this follow-up study was a multisite natural experiment with student-level random assignment based on retrospective lotteries that occurred prior to the start of the study. The study sought ECs that conducted admission lotteries long enough in the past so that students who participated in the lotteries would have had the opportunity to graduate from high school and enter postsecondary education by the time data collection concluded. The retrospective feature of the original study made it possible to estimate the EC impact on postsecondary outcomes within a relatively short time frame.

Specifically, to be eligible for the retrospective study, an EC had to meet the following criteria: (1) enrolled students in Grades 9–12, (2) had high school graduates by 2011, (3) used lotteries in its admission processes for at least one of three incoming student cohorts (i.e., students who entered ninth grade in 2005–06, 2006–07, or 2007–08), (4) retained the lottery records, and (5) implemented the ECHSI as a whole-school program. The study sample was restricted to ECs that were open by fall 2007 to ensure that students in the study would have had the opportunity to complete at least 2 years of college after expected high school graduation by the end of the original study (2013). For this follow-up study, we collected additional years of postsecondary data so that we would be able to examine student outcomes for 6 years following expected high school graduation for all three student cohorts included in the original impact study. Exhibit 2 illustrates the expected educational progression during the years covered by the original study and the follow-up study for each of the three student cohorts.

Exhibit 2. Students' Expected Educational Progression During the Periods Covered by the Original Impact Study and the Follow-up Study, by Cohort



Notes. HS = high school. Yx, x = 1–10: x years since starting high school. This exhibit depicts students' expected educational progression, assuming a 4-year high school program. Students may take more or less time to complete high school (two of the ECs in the study sample had 5-year programs).

Of the 154 ECs open nationwide by fall 2007, 10 met the criteria for inclusion in the original impact study. (See Appendix A for a CONSORT diagram illustrating sample selection.) These 10 schools are located in five states (i.e., North Carolina, Ohio, South Carolina, Texas, and Utah); five schools are located in urban areas, two in midsized cities, and three in small towns. Nine schools opened as new schools, and one was an existing school that became an EC. Eight of the

ECs had partnerships with 2-year colleges, and the other two had partnerships with 4-year colleges. All 10 schools were small schools (i.e., fewer than 150 students per grade) with enrollment ranging from about 100 to 600 students, with an average enrollment of 290. Across the 10 schools, 49% of the students were non-White (ranging from 12% to 100%), and 44% were eligible for free or reduced-price lunch (ranging from 9% to 99%) based on 2007–08 data.

Of the 10 ECs identified for the original study, 6 conducted admission lotteries for more than one student cohort, and 3 conducted multiple lotteries (i.e., "sublotteries") in a given year, such as separate lotteries for applicants from different feeder schools or districts. The original study included all students who participated in the 23 lotteries (including sublotteries) across three cohorts conducted by the 10 ECs, with students who were offered admission to the ECs identified as treatment students and students not offered admission identified as control students. In total, the study included 2,458 students (1,044 EC/treatment students and 1,414 control students). (See Appendix B for the number of students by condition in each lottery.) The control students were spread across 272 different high schools during the 4 years after participating in the EC admission lotteries, with many of those schools enrolling only one or two control students.

The background characteristics of the students who participated in our study are presented in Exhibit 3. Approximately half of the sample was female, half was non-White, and half was low income (i.e., eligible for free or reduced-price lunch). Fewer than a quarter of study participants had parents who did not attend college (i.e., first-generation college goers). Students who participated in the EC lotteries had average Grade 8 ELA and mathematics test scores that were above the state average. A comparison of the background characteristics between EC students and control students revealed small differences between groups, none of which are statistically significant at the .05 level, indicating that the two groups were equivalent at baseline.

Exhibit 3. Background Characteristics of EC Students and Control Students in the Impact Study Sample

Student Characteristic	EC Students (*N* = 1,044)	Control Students (*N* = 1,414)	Group Difference (Effect Size)	*p*-Value
Female	51.4%	52.9%	-0.04	.324
Nonwhite	51.8%	53.3%	-0.04	.362
Low-income	49.4%	47.3%	0.05	.312
First-generation college-going	23.9%	22.8%	0.04	.368
Grade 8 ELA test score	0.212	0.133	0.08	.068
Grade 8 mathematics test score	0.227	0.236	-0.01	.392

*Note*s. The means for EC students are unadjusted means; the means for control students were computed by subtracting the estimated group mean difference from the unadjusted means for EC students. All baseline equivalence tests were conducted using two-level models that were similar to the main impact model (see Appendix D).

Data Sources

Data for the original study came from a variety of sources. Information about who participated in the EC admission lotteries and who was offered admission to the EC was obtained from the ECs. Students' demographic information and achievement on Grade 8 state assessments were obtained from participating districts and states. Data for students who applied to ECs in North Carolina came from a longitudinal experimental study on ECs led by the University of North Carolina at Greensboro SERVE Center. The student demographic and prior achievement data collected in the previous study continue to be available for this follow-up study for all but one EC, which is in a state that no longer allows researchers access to identifiable student-level demographic and achievement data. Demographic and prior achievement data for all EC and control students from this site were imputed for the follow-up study.[2] While we included this site in the main impact analyses, we performed a set of sensitivity analyses in which this site was excluded.[3]

In addition to extant administrative records, the original study collected information about students' perceptions of their high school experiences through a student survey conducted in winter 2011/spring 2012. The survey was given only to the two youngest cohorts (i.e., students who entered ninth grade in 2006–07 and 2007–08) because pilot work indicated that older students were harder to locate and had difficulty remembering details of their high school experiences. Eight of the 10 ECs in the study sample participated in the survey; the other two ECs did not participate because they could not provide the student contact information needed to administer the survey. Based on a power analysis conducted during the design phase of the original study, 1,424 students (771 EC students and 653 control students) from the eight ECs were sampled for the survey, representing 58% of the total study sample. The survey response rate was 93% for the EC students and 87% for the control students, with an overall response rate of 90%. (See Appendix B for the number of survey respondents for each lottery.)

Finally, the original study obtained data on students' enrollment in postsecondary education and degree completion as of fall 2013 using the StudentTracker Service at the National Student Clearinghouse (NSC). This follow-up study collected additional years of NSC data in winter 2017, allowing for between 6 years (for Cohort 3 students) and 8 years (for Cohort 1 students) of data after expected high school graduation for students in our study sample. The NSC collects data on student enrollment and degree completion from more than 3,600 degree-granting higher education institutions across the United States, and it currently covers more than 98% of all student enrollments in public and private colleges and universities in the United States (NSC, 2017). For a

[2] Most of the students from this site took the student survey, and the available survey data were used to impute student demographic and prior achievement data for this site.
[3] In addition, for outcome measures that are common between the original EC impact study (Berger et al., 2013) and this follow-up study, we compared results between the original study (for which we had unimputed data for this site) and the follow-up study (for which we had imputed data for this site). Overall, results were similar between studies.

small percentage of college students, the NSC cannot provide their postsecondary data because their colleges did not report data to the NSC[4] or because the students refused to allow their records to be released (Dynarski, Hemelt, & Hyman, 2015). Because the NSC data do not allow researchers to distinguish a student who did not attend college from a student with missing records for the reasons stated, estimates of college enrollment rates and degree completion rates based on the NSC data may be slightly lower than the actual rates. However, given that the number of missing records from NSC is very small, their influence on the results from this study is likely to be negligible.

Measures

In this section, we provide a description of all of the measures used in our statistical models.

Outcome Measures

This follow-up study examined student outcomes in two outcome domains with three primary outcomes in each domain:

1. **Outcomes in the College Enrollment Domain:** Enrolled in college, enrolled in a 2-year college, and enrolled in a 4-year college within 6 years after expected high school graduation (i.e., by Year 10).
2. **Outcomes in the Degree Attainment Domain:** Completed any postsecondary degree, completed an associate's degree or a certificate, and completed a bachelor's degree within 6 years after expected high school graduation (i.e., by Year 10).

For the three primary outcomes in the degree attainment domain, we used "within 6 years after expected high school graduation" as the time frame, as it is an approximation of the standard time frame (i.e., 150% of normal time of degree completion) that colleges use to report to the National Center for Education Statistics (NCES) on the completion of bachelor's degrees in compliance with the 1990 Student Right to Know Act.[5] In the NCES Integrated Postsecondary Education Data System (IPEDS), the time frame for degree completion begins when students enroll in college for the first time rather than when they graduate from high school. Therefore, our measure of degree completion is equivalent to the IPEDS measure of degree completion for

[4] In fall 2009, which is the fall immediately after expected high school graduation for the oldest student cohort in our study, the NSC obtained enrollment data from 96.5% of all public 4-year colleges and 94.6% of all public 2-year colleges nationally. The coverage was lower in the private sector: 85.3% of private 4-year colleges and 14.8% of private 2-year colleges. Even though the NSC coverage of private 2-year colleges is low, it should have only minimal influence on estimated enrollment or degree completion rates because enrollment in this sector represents only approximately 2% of the total postsecondary enrollment in the nation.
[5] NCES also reports rates of degree completion both within 100% of normal time and within 200% of normal time of degree completion.

students who graduated from high school within 4 years of high school entry and entered college for the first time immediately after high school graduation.[6]

To obtain a more comprehensive picture of the EC impact on college enrollment and degree attainment over time, we also examined whether students enrolled in college, enrolled in a 2-year college, enrolled in a 4-year college, completed any type of postsecondary degree, or completed an associate's degree or a certificate by the end of each year from Year 4 after entering ninth grade through 6 years after expected high school graduation (i.e., Year 10).[7] Because students are not expected to earn more than 2 years of college credit during high school, we examined whether students completed a bachelor's degree between 2 and 6 years after expected high school graduation. (See Appendix C for a list of all outcome measures examined in this study with their definitions.)

The measures of college enrollment described above are not mutually exclusive; over the period covered by this study, students may enroll in both 2-year and 4-year colleges. To provide a detailed snapshot of students' postsecondary enrollment status within each year between Year 5 (i.e., the first year after expected high school graduation) and Year 10 (i.e., the sixth year after expected high school graduation),[8] we also examined a series of categorical measures of students' enrollment profiles at each point in time. Within each given year, students were classified into one of four mutually exclusive categories: (1) not yet enrolled in college, (2) enrolled exclusively in 2-year colleges, (3) ever enrolled in a 4-year college with a prior enrollment in a 2-year college,[9] or (4) ever enrolled in a 4-year college without prior enrollment in a 2-year college. Once students enrolled in a 4-year college (either with or without a prior enrollment at a 2-year college), they remained in that category in subsequent years. Similarly, students who enrolled exclusively in 2-year colleges remained in that category in subsequent years unless they transferred to a 4-year college.

Finally, to further explore EC impact on the types of colleges in which students enroll, we examined differences between EC and control students in enrollment in selective 4-year colleges each year from Year 4 after entering ninth grade through 6 years after expected high school graduation. The selectivity of postsecondary institutions was determined using information from

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[6] Our measures of degree completion also differ from the IPEDS measures in that the IPEDS measures capture only those degrees that were obtained from the first college that students attended, whereas our measures are based on the NSC data that capture degrees obtained from any college that students attended.
[7] Results for completion of an associate's degree or a certificate within 3 years after expected high school graduation (i.e., by Year 7) will approximate the NCES definition of associate's degree completion (i.e., approximately 150% of normal time for completing an associate's degree).
[8] For this analysis, we do not look at enrollment profiles during the fourth year of high school due to the relatively small number of control students who enrolled in college during high school.
[9] Category (3) is intended to capture students who started at a 2-year college and then transferred to a 4-year college. There are a small number of students in our sample who started at a 4-year college, then went to a 2-year college, and later transferred back to a 4-year college. Those students were considered as belonging to Category (4) for the purpose of this study.

the *Barron's Profiles of American Colleges* (2008, 2010, 2012, 2014, 2016, 2017, 2018). Barron's identifies selective colleges based on the percentage of applicants who are admitted into the institution as well as the achievement characteristics of incoming freshmen students. For this study, we define selective colleges as colleges that were classified as "most competitive" or "highly competitive" by Barron's in the year in which students enrolled in the college. These are colleges in which no more than 50% of the applicants are offered enrollment, with incoming students having grade point averages of a B or higher and coming from the top 35% of their high school class. Median SAT scores at these colleges exceed 620, and median ACT scores exceed 27. Each year, between 176 and 196 colleges were identified by Barron's as "most competitive" or "highly competitive." Annual information from Barron's was merged with student data to determine that colleges were classified as selective during the academic year in which study participants were enrolled in the college. Because *Barron's Profiles of American Colleges* was not printed every year during the period examined in this study, we were unable to obtain lists from Barron's for the 2008–09, 2010–11, 2012–13, and 2015–16 academic years. For these years, we relied on the list of colleges from the previous year.

Given that the study includes multiple outcomes in each outcome domain, there may be increased risk for inflated Type I error due to multiple comparisons. To guard against such risk, we have designated a single outcome in each outcome domain (i.e., ever enrolled in college and ever completed a postsecondary degree or certificate) as the "confirmatory" outcome, and our main conclusion about the treatment effect in each domain is based on the confirmatory outcome. To check the robustness of our findings to potentially increased Type I error due to multiple comparisons, we also used the Benjamini-Hochberg method to correct for multiple comparisons within each outcome domain, as recommended by the WWC (2017b). Because there are three primary outcome measures within each outcome domain, we corrected for three comparisons within each domain.

Moderators and Covariates

Given the focus of the ECHSI on students who are disadvantaged, we expect that the EC impact may vary across different types of students (RQ2). To test this hypothesis, we conducted moderator analyses with the following measures of student background characteristics as potential moderators: gender, race/ethnicity (White versus non-White), low-income status (eligibility for free or reduced-price lunch), and eighth-grade mathematics and ELA achievement scores (standardized based on state means and standard deviations). Data on all these measures were collected from administrative records for the original impact evaluation. These measures also were used as covariates to improve the precision of estimates in all our analyses. In addition, the student survey administered for the original impact study in winter 2011/spring 2012 asked students about their parents' level of education. Impact models included a covariate indicating whether students reported that neither of their parents attended college.[10] Finally, while we also collected student-level data about English language learner (ELL) status and Individualized Education Program (IEP) status before entering high school, only a small percentage of students in our sample were ELLs (less than 1%) or had IEPs (7%). Therefore, we did not include these two variables as covariates in the impact analyses.

Mediators

As indicated by the EC theory of change (see Exhibit 1), we hypothesize that the EC impact on student outcomes is mediated by students' high school experiences (RQ3). To test this hypothesis, we conducted mediation analyses with four mediators measuring key aspects of students' high school experiences based on the student survey administered in winter 2011/spring 2012 in the original impact study (see Exhibit 4).

Exhibit 4. Measures of Students' High School Experiences as Potential Mediators of EC Impact

Potential Mediator	Description
College credit accrual during high school[a]	A dichotomous indicator of whether a student (1) earned any college credit in high school or (2) passed at least one advanced placement exam
Instructional rigor	An eight-item scale ranging from 0 (*never*) to 4 (*almost every day*) measuring the frequency with which students reported defending their ideas, writing five or more pages on a topic, explaining thinking, applying what they had learned, engaging in discussions, doing research, presenting work, and receiving feedback in courses that they took during Grades 9–12; reliability (α) = .82
College-going culture	A three-item scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*) measuring the extent to which the principal, teachers, and students expected students in the high school to go to college; reliability (α) = .79
Student support	A five-item scale ranging from 1 (*strongly disagree*) to 4 (*strongly agree*) measuring the extent to which teachers cared if students came to school, praised students for their effort, listened to students, encouraged students, and cared about students; reliability (α) = .88

[a] Because college credit accrual during high school implies college enrollment, we examined college credit accrual during high school as a potential mediator only for EC impact on degree attainment outcomes, not for college enrollment outcomes.

Analytic Methods

In this section, we briefly describe the methods we used to address the three RQs guiding this study. Further technical details on our analytic methods can be found in Appendix D.

[10] Because of the relatively large amount of missing data for first-generation college-going status due to both survey nonresponse and sampling procedures (i.e., students in the oldest cohort did not participate in the student survey), we did not examine differences in EC impact by first-generation status. Overall, 33.3% of treatment students and 60.8% of control students in our study had missing data on first-generation status.

Main Impact Analyses

Our main impact analyses are intent-to-treat (ITT) analyses, which estimate the impact of being offered admission to an EC through a lottery, regardless of whether students actually enrolled in the EC. To estimate overall ITT effects across lotteries, we constructed a two-level logistic regression model that takes into account the clustering of students within lotteries. Given the limited number of lotteries in the study sample, we treated lotteries as fixed effects in our main ITT analyses, and we also estimated random-effects models for the six primary outcomes as sensitivity analyses. All ITT analyses controlled for students' demographic characteristics and Grade 8 achievement to improve the precision of impact estimates.

For the categorical outcome of postsecondary enrollment profile in a given year, our ITT analysis was based on a multinomial logistic regression model where the outcome has four possible categories: (1) had not enrolled in college (the baseline category), (2) enrolled exclusively in 2-year colleges, (3) ever enrolled in a 4-year college with a prior enrollment in a 2-year college, and (4) ever enrolled in a 4-year college without a prior enrollment in a 2-year college as of the given year. The model estimates the EC impact on the probability of being in a particular outcome category relative to the probability of being in the baseline category (i.e., impact on the relative risk ratio), while controlling for lottery/sublottery fixed effects and student background characteristics.[11]

Given that not all lottery participants complied with their treatment assignment, we supplemented the ITT analyses with complier average treatment effect (CATE) analyses for the six primary outcomes measured 6 years after expected high school graduation: enrollment in college, enrollment in a 2-year college, enrollment in a 4-year college, completion of a postsecondary degree, completion of an associate's degree or certificate, and completion of a bachelor's degree. Relying on an instrumental variable approach, the CATE analyses explicitly take into account noncompliance with treatment assignment (i.e., no-shows and crossovers), and estimate the average treatment effects of actually attending an EC for students who complied with their treatment assignment rather than the average treatment effects of being offered admission to an EC through a lottery (i.e., the ITT effects). (See Appendix D for further details about both the ITT and CATE analyses.)

Differential Impact Analyses

To answer the second research question about potential differential impacts of ECs on students with different background characteristics, we added an interaction between treatment status and a given student characteristic into the student-level equation of the main ITT impact model.

[11] One sublottery was removed from this set of analyses because all six participants in this sublottery had enrolled in college within 2 years after expected high school graduation (i.e., by Year 6), and therefore the relative risk ratio is undefined for this sublottery beyond Year 6.

We explored whether the EC impacts on the six primary outcomes for the study differed significantly by students' gender, minority status, low-income status, and level of prior mathematics and ELA achievement.[12]

Mediation Analyses

To address RQ3, we explored whether the impacts of ECs on college enrollment and degree completion within 6 years after expected high school graduation (i.e., by Year 10) were mediated by students' high school experiences as measured by *college credit accrual during high school, instructional rigor, college-going culture,* and *student support* (see Exhibit 4 for details about these measures). Because college credit accrual during high school implies college enrollment, we examined college credit accrual during high school as a potential mediator only for EC impact on degree completion outcomes, not for college enrollment outcomes. Given that data on high school experiences were collected through the student survey administered only to the two youngest cohorts in the study, these analyses were limited to the 1,424 students who were included in the survey sample.

For a measure to explain or mediate the EC impact, three conditions must be met: (1) there must be a relationship between the treatment status and the mediator, (2) the mediator must be related to the student outcome, and (3) there should be no unmeasured confounders of the relationship between the mediator and the outcome (Imai, Keele, & Yamamoto, 2010; Keele, 2015; MacKinnon & Dwyer, 1993).[13] To assess the extent to which the total effects of ECs on students' postsecondary outcomes were mediated by students' high school experiences, we first estimated the EC impacts on students' high school experiences, and then estimated the effects of high school experiences on students' postsecondary outcomes while controlling for treatment status and a rich set of student background characteristics that might be related to both their high school experiences and outcomes. Based on the results from these analyses, we were able to decompose the total EC impact on a given outcome into a direct effect and an indirect effect as mediated through students' high school experiences. (See Appendix D for details of the mediation analyses.)

Handling of Missing Data

By design, all students in the study have data on the outcome measures based on NSC data; however, not all students have data on all measures of student background characteristics, and some student survey respondents have missing data on high school experience measures. Rates

[12] In two of the 23 lotteries, all EC students were minorities; therefore, these two lotteries were excluded from the analysis of differential impact by minority status. In addition, one lottery was excluded from the analysis of differential impact by low-income status because no students in this lottery were qualified for free or reduced-price lunch.

[13] The third condition is referred to as the "sequential ignorability" assumption in the causal mediation literature (Imai et al., 2010; Keele, 2015). To the extent that our mediation models may not include all covariates that may explain the relationships between the mediators and outcomes, the results from these analyses should be interpreted with caution.

of missing data for the student background characteristics and measures of high school experiences can be found in Appendix E. To address the potential selection bias that would result from excluding cases with missing data, we imputed missing values on the covariates using multiple imputation by chained equations (Raghunathan, Lepkowski, Van Hoewyk, & Solenberger, 2001). The multiple imputation model included all outcome measures, covariates, interaction terms, and mediators used in addressing the RQs, as well as indicators for treatment status and lotteries. We generated 10 imputed data sets, conducted all analyses using each imputed data set separately, and then combined estimates across the 10 data sets based on standard multiple imputation combination rules, which take into account the uncertainty in imputed values both within and across the imputed data sets (Little & Rubin, 2002).

Results

In this section, we present the main findings for each of the three RQs guiding the study. Further details about the main findings and additional findings from sensitivity analyses are provided in Appendices F and G, respectively.

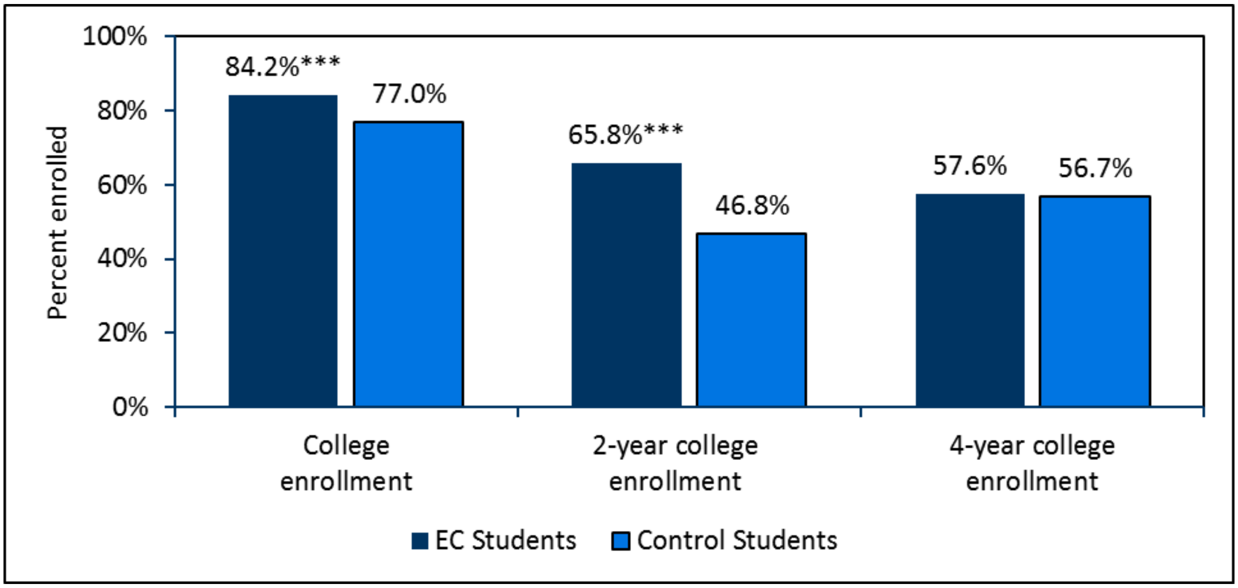
EC Impacts on Student Outcomes (RQ1)

RQ1 of the study focuses on the overall impacts of ECs on students' postsecondary outcomes. Below we first present findings about EC impacts on outcomes in the college enrollment domain, including enrollment in different types of colleges and enrollment profiles over time, and then we present findings related to EC impacts on outcomes in the degree attainment domain.

ITT Impact on College Enrollment

Our analysis showed that being admitted to an EC had a statistically significant, positive impact on college enrollment within 6 years after expected high school graduation (i.e., by Year 10): 84.2% of EC students had at least one record of college enrollment in the NSC during the time period, roughly 7 percentage points higher than the college enrollment rate for control students (77.0%, see Exhibit 5). This difference was driven primarily by the much higher rate of enrollment in 2-year colleges for EC students (65.8%) than for the control students (46.8%). The two groups of students did not significantly differ in the rate of enrolling in 4-year colleges by the end of the sixth year after expected high school graduation (57.6% of EC students compared with 56.7% of control students).

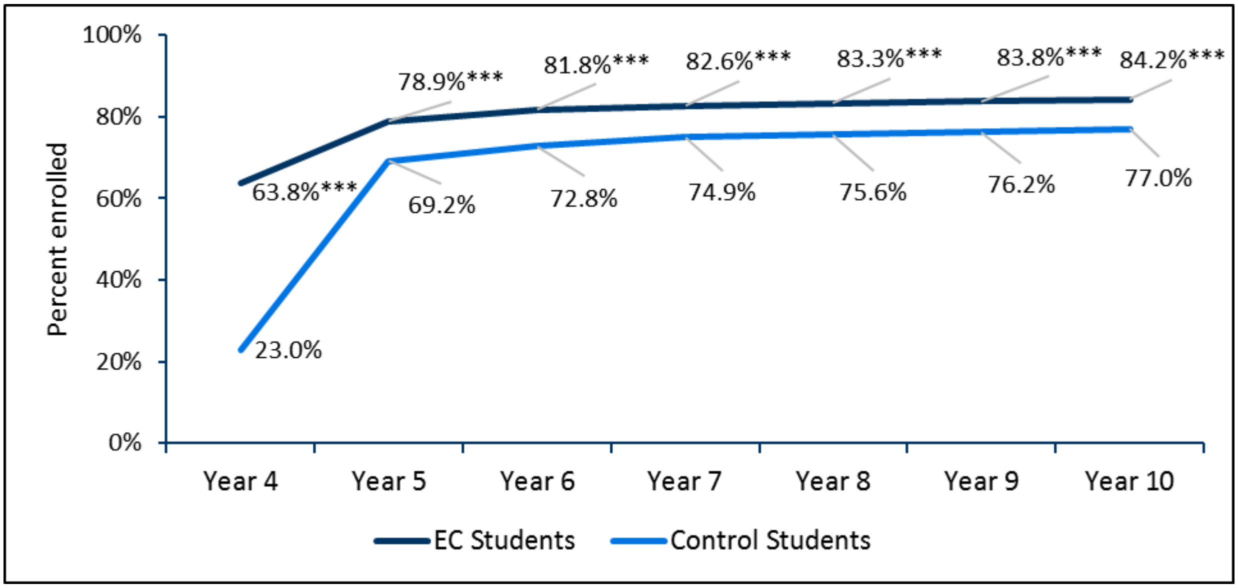
Exhibit 5. Percentage of Students Who Enrolled in College Within 6 Years After Expected High School Graduation, by Type of College and Study Group



Notes. *N* = 2,458 (1,044 EC, 1,414 control). The percentages for EC students are unadjusted percentages; the percentages for control students were computed based on the unadjusted percentages for EC students and estimated EC effects.
*** $p < .001$.

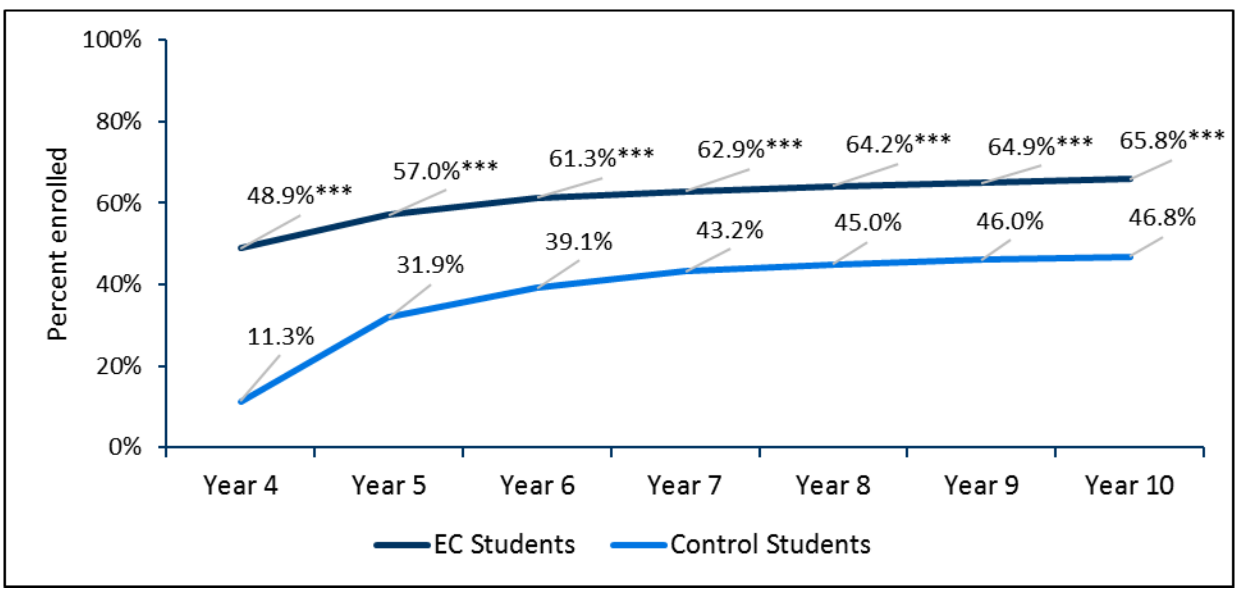
For both enrollment in any type of postsecondary institutions and enrollment in 2-year colleges, we found that winning an EC lottery had a significant impact on enrollment rates by the end of each year between Year 4 (i.e., the fourth year of high school) and Year 10 (i.e., 6 years after expected high school graduation), although the size of the impact tended to decrease over time (see Exhibits 6 and 7). By the end of Year 4, 63.8% of EC students and 23.0% of control students had enrolled in college, a difference of more than 40 percentage points. By the end of Year 5, this difference was reduced to about 10 percentage points, and by the end of Year 10, this difference was further reduced to about 7 percentage points. Similarly, the difference in enrollment in 2-year colleges by the end of Year 4 was almost 38 percentage points (48.9% of EC students compared with 11.3% of control students). This difference decreased to about 25 percentage points by the end of Year 5, and further decreased to 19 percentage points but remained statistically significant by the end of Year 10.

Exhibit 6. Percentage of Students Who Enrolled in Any Colleges Between Year 4 and Year 10, by Study Group



Notes. *N* = 2,458 (1,044 EC, 1,414 control). The percentages for EC students are unadjusted percentages; the percentages for control students were computed based on the unadjusted percentages for EC students and estimated EC effects. Year x, x = 4~10, refers to x years after starting high school.
*** *p* < .001.

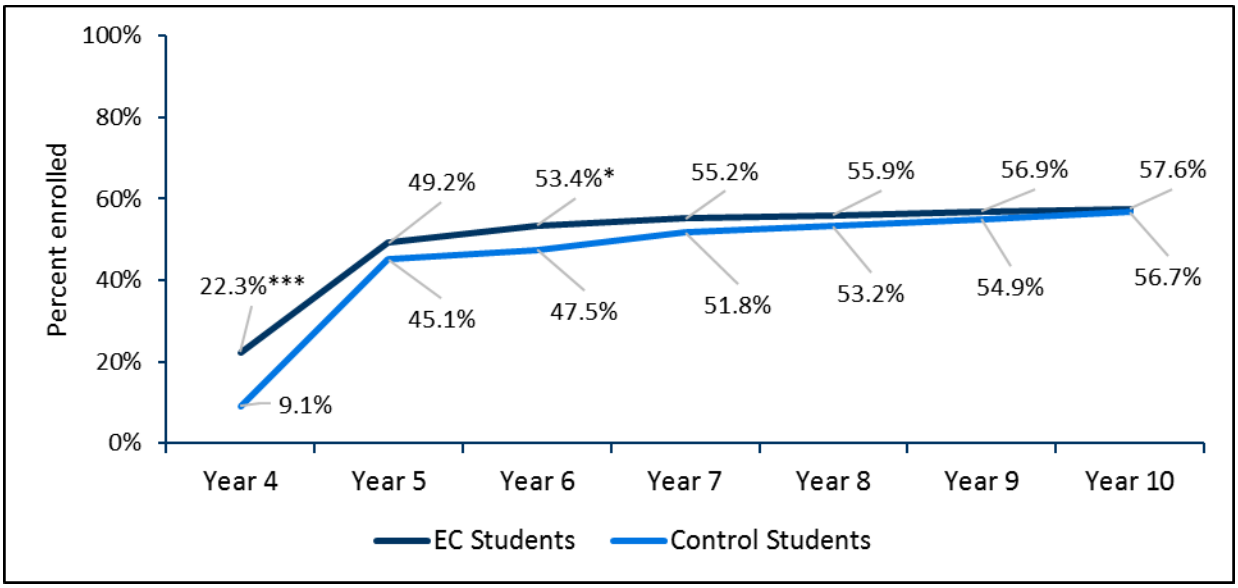
Exhibit 7. Percentage of Students Who Enrolled in 2-Year Colleges Between Year 4 and Year 10, by Study Group



Notes. *N* = 2,458 (1,044 EC, 1,414 control). The percentages for EC students are unadjusted percentages; the percentages for control students were computed based on the unadjusted percentages for EC students and estimated EC effects. Year x, x = 4~10, refers to x years after starting high school.
*** *p* < .001.

A general decline over time in the size of the EC impact is also evident for enrollment in 4-year colleges. As Exhibit 8 shows, by the end of Year 4 (i.e., the fourth year of high school), 22.3% of EC students had enrolled in 4-year colleges compared with 9.1% of control students—a statistically significant difference of approximately 13 percentage points. This difference decreased to less than 5 percentage points (which was no longer statistically significant) by the end of Year 5, but widened slightly to about 6 percentage points by the end of Year 6, a difference that achieved statistical significance.[14] After Year 6, the EC impact on the rate of enrollment in 4-year colleges further declined and was no longer statistically significant.

Exhibit 8. Percentage of Students Who Enrolled in 4-Year Colleges Between Year 4 and Year 10, by Study Group



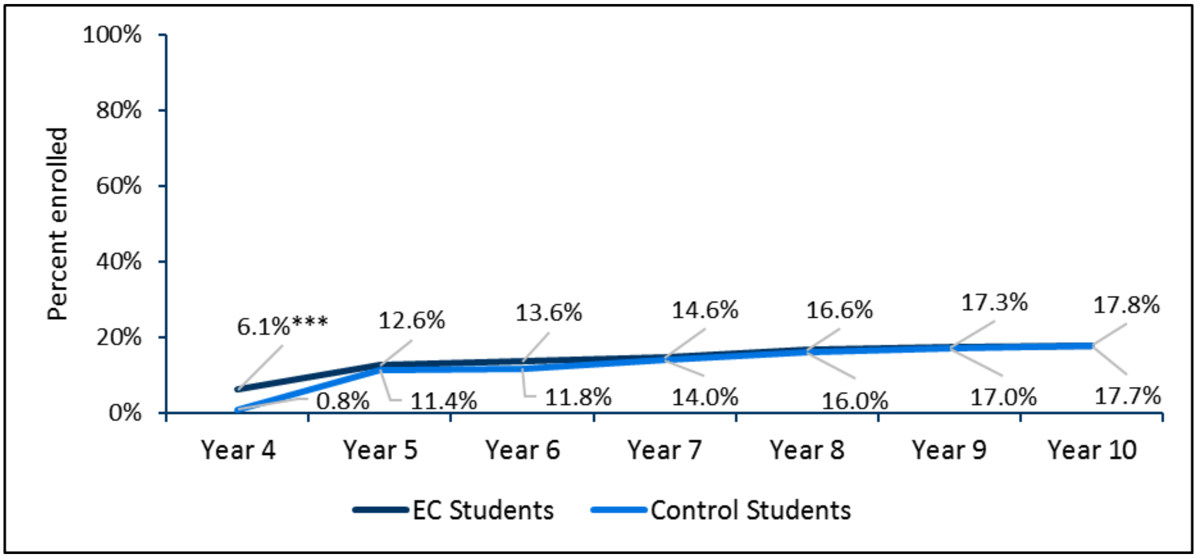
Notes. *N* = 2,458 (1,044 EC, 1,414 control). The percentages for EC students are unadjusted percentages; the percentages for control students were computed based on the unadjusted percentages for EC students and estimated EC effects.
Year x, x = 4~10, refers to x years after starting high school.
* *p* < .05; *** *p* < .001.

To further examine whether there was an EC impact on the type of institutions that students attended, we estimated EC impacts on enrollment in selective 4-year colleges as defined by *Barron's Profiles of American Colleges* (2008, 2010, 2012, 2014, 2016, 2017, 2018). As illustrated in Exhibit 9, while EC students were significantly more likely than control students to enroll in selective 4-year colleges in the fourth year of high school (6.1% of EC students compared with 0.8% of control students), the two groups of students did not differ significantly

[14] Two of the ECs in the study have 5-year programs. It is likely that many students from these two ECs enrolled in 4-year colleges in Year 6—the first year after their expected high school graduation—rather than in Year 5 when they were still in high school. This may be one potential explanation for the increased EC-control gap in the rate of enrollment in 4-year colleges between Year 5 and Year 6.

in their enrollment in selective 4-year colleges after expected high school graduation. By the end of Year 10, approximately 18% of both EC students and control students had enrolled in selective 4-year colleges.

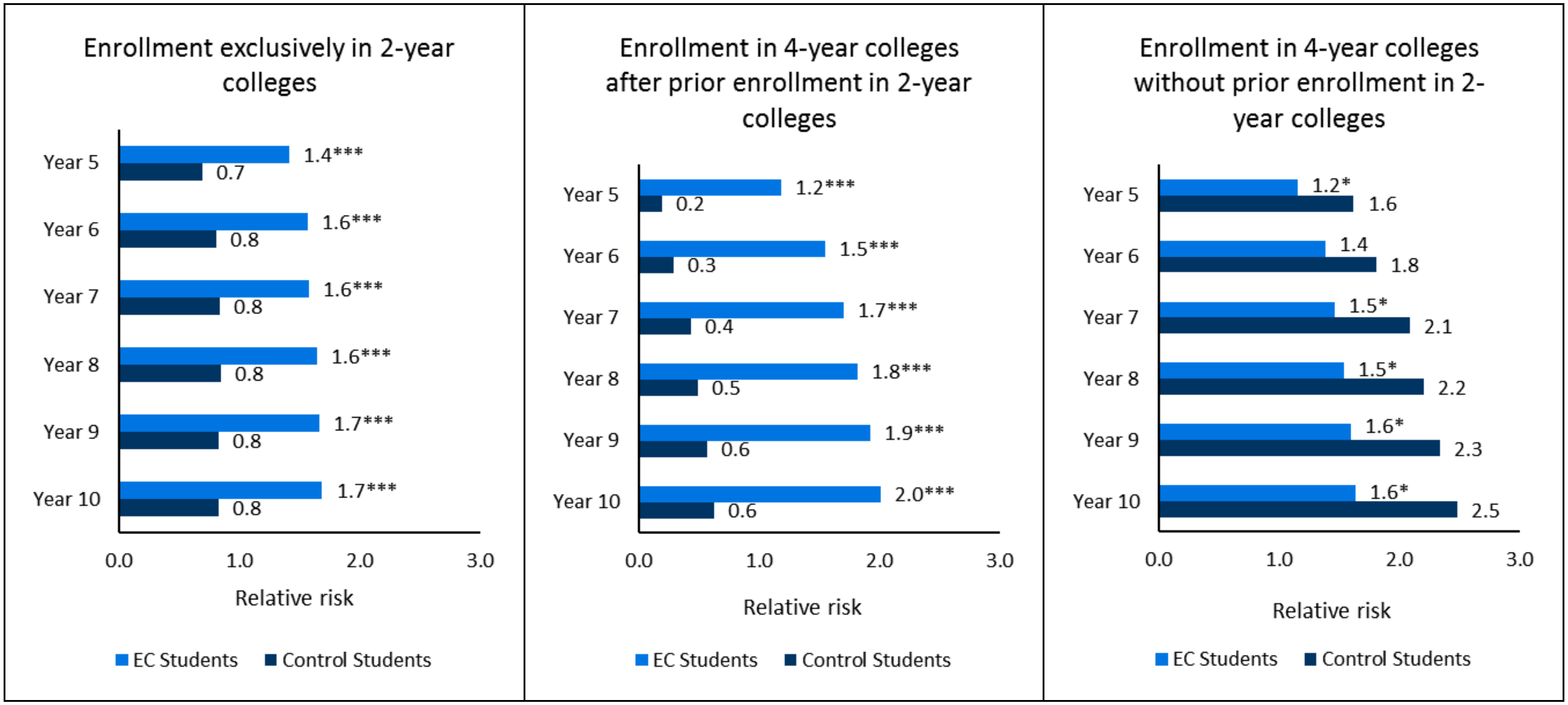
Exhibit 9. Percentage of Students Who Enrolled in Selective 4-Year Colleges Between Year 4 and Year 10, by Study Group



Notes. *N* = 2,458 (1,044 EC, 1,414 control). The percentages for EC students are unadjusted percentages; the percentages for control students were computed based on the unadjusted percentages for EC students and estimated EC effects. Year x, x = 4~10, refers to x years after starting high school.
*** $p < .001$.

To gain a more complete picture of the EC impact on students' college enrollment, we further examined students' enrollment profiles in each year between 1 year and 6 years after expected high school graduation (i.e., between Year 5 and Year 10), which allowed us to track students' progression over time through their academic careers. In each year, students were classified into one of four categories: (1) had not yet enrolled in college (i.e., the baseline category), (2) ever enrolled exclusively in 2-year colleges, (3) ever enrolled in a 4-year college with a prior enrollment in a 2-year college, or (4) ever enrolled in a 4-year college without a prior enrollment in a 2-year college. Based on a multinomial logistic regression analysis, we estimated the EC impact on the relative risk for each of the last three categories in each given year, which is defined as the ratio of the probability of being in a particular enrollment category to the probability of being in the baseline category by the end of the given year. A relative risk that is greater than 1 indicates that students are more likely to belong in the specified enrollment category relative to not having enrolled in college. In contrast, a relative risk that is less than 1 indicates that students are less likely to belong in the specified enrollment category relative to not having enrolled in college. The relative risks for EC and control students based on this set of analyses are presented in Exhibit 10.

Exhibit 10. Relative Risks Associated With Each Postsecondary Enrollment Category Between Year 5 and Year 10, by Study Group



Notes. *N* = 2,452 (1,041 EC, 1,411 control). Relative risk is defined as the probability of being in a given enrollment category relative to the probability of not having enrolled in college (i.e., the baseline category). Relative risks for EC students were computed based on the unadjusted percentage of EC students in each of the enrollment categories. Relative risks for control students are adjusted relative risks that were computed based on the unadjusted relative risks for EC students and estimated EC effects.
Year x, x = 5~10, refers to x years after starting high school.
* $p < .05$; *** $p < .001$.

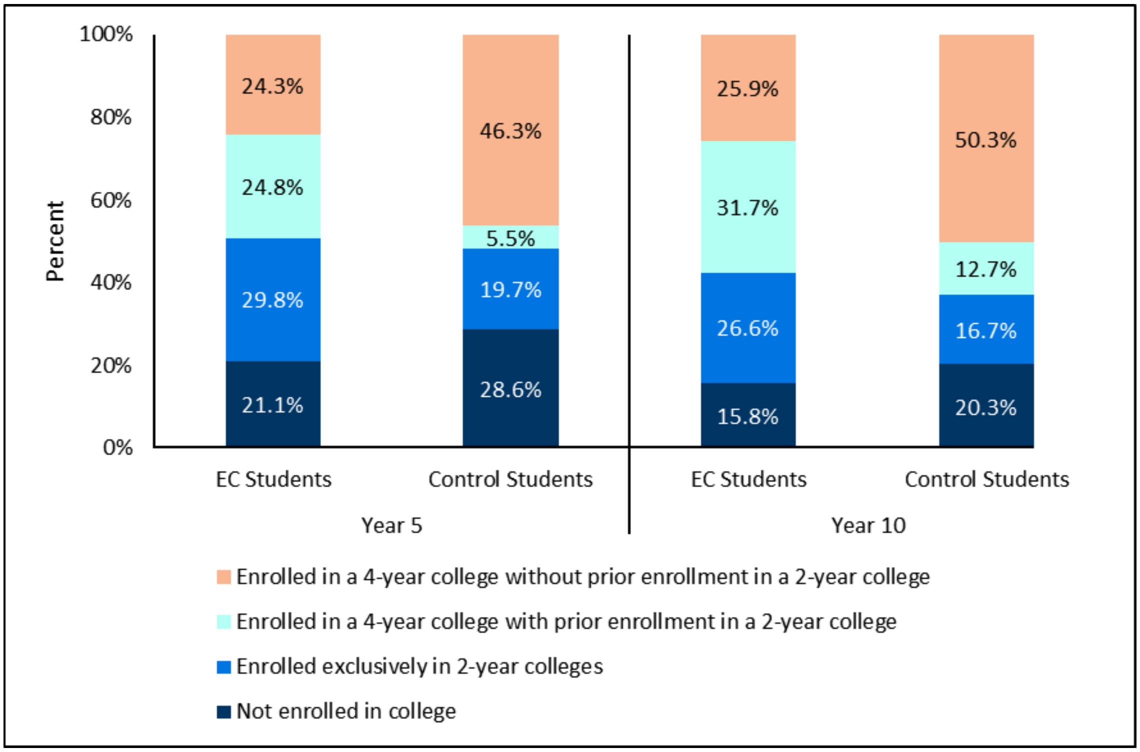
As demonstrated in the first two panels of Exhibit 10, in each year between Year 5 and Year 10, EC students were more likely to have "enrolled exclusively in 2-year colleges" and "enrolled in a 4-year college with a prior enrollment in a 2-year college" than to have not enrolled in college, with relative risks greater than one for both enrollment categories. In contrast, the relative risks for both categories are less than one for the control students in each year examined, indicating that control students were *less* likely to be in these enrollment categories than in the baseline category (i.e., had not enrolled in college). These differences between EC students and control students in each year examined were statistically significant ($p < .001$).

The third panel of Exhibit 10 shows the relative risks associated with "enrolling in a 4-year college without a prior enrollment in a 2-year college" in each year between Year 5 and Year 10 for EC students and control students. For each year examined, the relative risk was lower for EC students than for control students, and the difference was statistically significant ($p < .05$) for all years examined except Year 6. Taken together, results in Exhibit 10 show that EC students were more likely to enroll in a 4-year college after starting their education at a 2-year college, while control students were more likely to start at a 4-year college without a prior enrollment at a 2-year college.

To facilitate the interpretation of the results about students' postsecondary enrollment profiles, Exhibit 11 presents the distribution of EC students and control students across the four enrollment categories in two select years—1 year after expected high school graduation (Year 5) and 6 years after expected high school graduation (Year 10). Clearly, the two groups of students manifested different enrollment profiles. Mirroring our main impact estimates, Exhibit 11 shows that the percentage of EC students who had not enrolled in college was lower than the percentage for control students by Year 5 (21.1% vs. 28.6%) and Year 10 (15.8% vs. 20.3%). The percentage of EC students who had enrolled in a 4-year college without a prior enrollment at a 2-year college was also lower than that for control students by Year 5 (24.3% vs. 46.3%) and Year 10 (25.9% vs. 50.3%). The percentages of EC students in the other two enrollment categories (i.e., enrolled exclusively in 2-year colleges and enrolled in a 4-year college after a prior enrollment in a 2-year college), however, were both much higher than the percentages for control students by Year 5 and Year 10.[15]

[15] The percentage of students classified as having "enrolled exclusively in 2-year colleges" decreased between Year 5 and Year 10 as some students transferred from 2-year to 4-year colleges, thus being reclassified as "enrolled in a 4-year college with a prior enrollment in a 2-year college."

Exhibit 11. Percentage of Students in Each Postsecondary Enrollment Category 1 Year and 6 Years After Expected High School Graduation, by Study Group



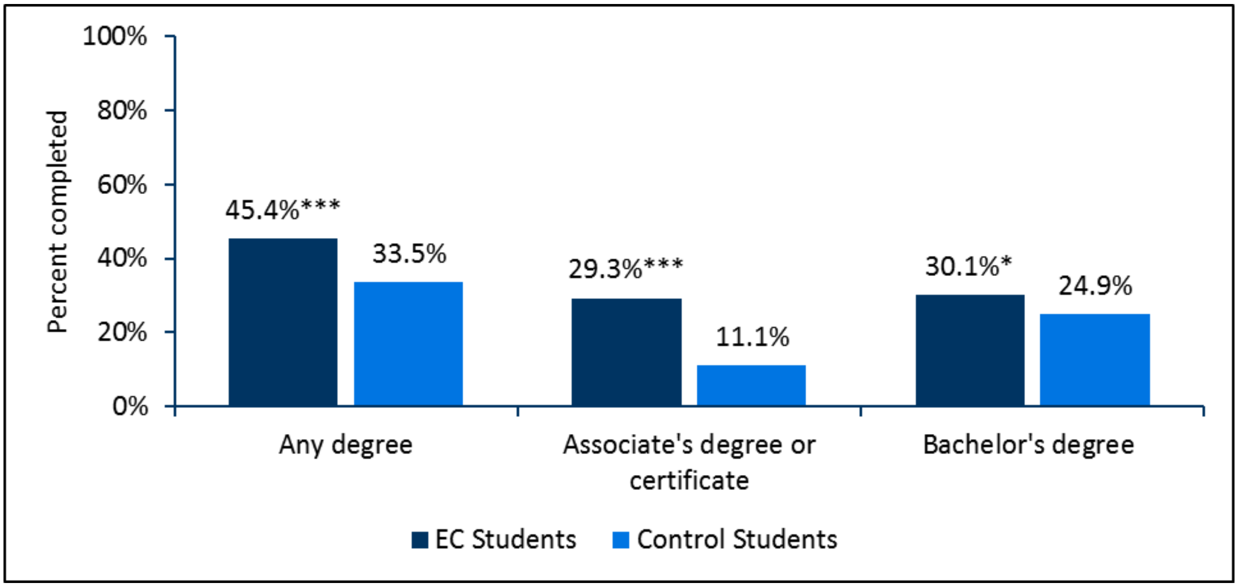
Notes. *N* = 2,452 (1,041 EC, 1,411 control). The percentages for EC students are unadjusted percentages; the percentages for control students were computed based on the unadjusted percentages for EC students and estimated EC effects.
Year x, x = 5, 10, refers to x years after starting high school.

In summary, our findings show that EC students were significantly more likely than control students to enroll in 2-year colleges, and they were also significantly more likely to transfer from 2-year colleges to 4-year colleges over time. Control students, in contrast, were significantly more likely than EC students to enroll in 4-year colleges without prior enrollment in 2-year colleges. Taken together, we did not observe significant differences between EC and control students in overall enrollment in 4-year colleges over time.

ITT Impact on Degree Attainment

The results for the EC impact on the primary outcome measures of degree attainment are summarized in Exhibit 12. Within 6 years after expected high school graduation (i.e., by the end of Year 10), 45.4% of EC students completed postsecondary degrees, compared with 33.5% of control students ($p < .001$). This 12-percentage-point difference was largely driven by the difference between the two study groups in the percentage of students who completed an associate's degree or certificate by the end of Year 10—29.3% of EC students compared with 11.1% of control students, a difference exceeding 18 percentage points ($p < .001$). The difference between the study groups in bachelor's degree completion by the end of Year 10 was much smaller yet still statistically significant—5.2 percentage points (30.1% of EC students compared with 24.9% of control students, $p < .05$).

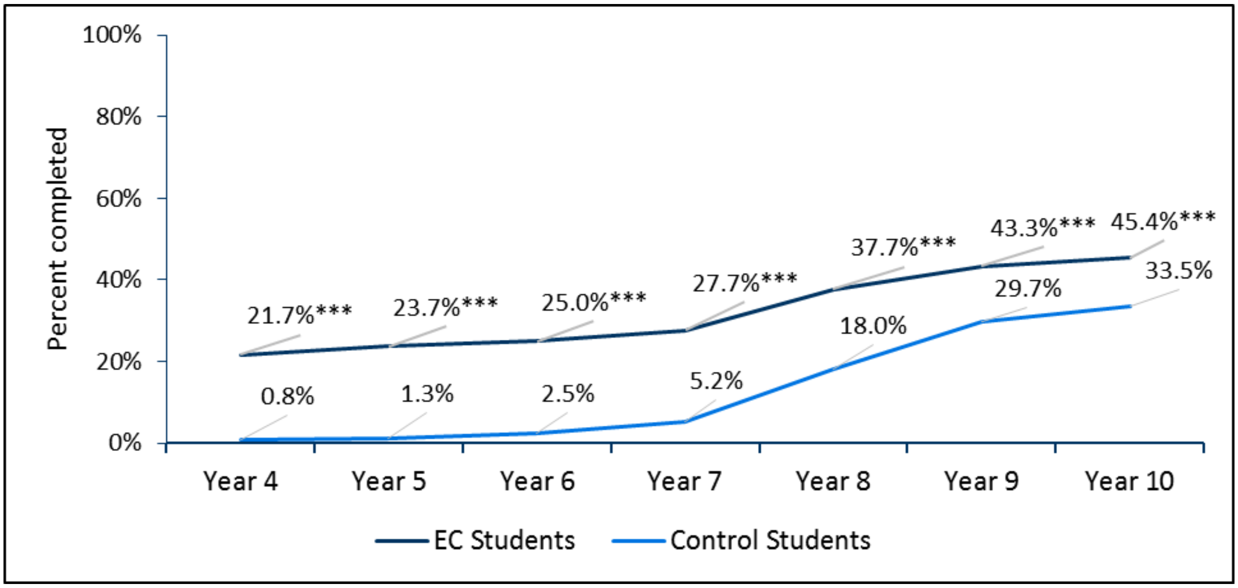
Exhibit 12. Percentage of Students Who Completed a College Degree Within 6 Years After Expected High School Graduation, by Type of Degree Completed and Study Group



Notes. *N* = 2,458 (1,044 EC, 1,414 control). The percentages for EC students are unadjusted percentages; the percentages for control students were computed based on the unadjusted percentages for EC students and estimated EC effects.
* $p < .05$; *** $p < .001$.

Further analyses revealed that being admitted to an EC had a significant, positive impact on degree completion by the end of each year between Year 4 and Year 10 (see Exhibit 13). While the difference in degree completion rate between the EC students and control students remained statistically significant over time, the size of the difference decreased from a maximum of 22.5 percentage points (by the end of Year 6 and Year 7) to 11.9 percentage points (by the end of Year 10). This indicates that, over time, control students began to "catch up" to EC students in terms of degree completion, but a significant difference between the two groups of students remained 6 years after expected high school graduation.

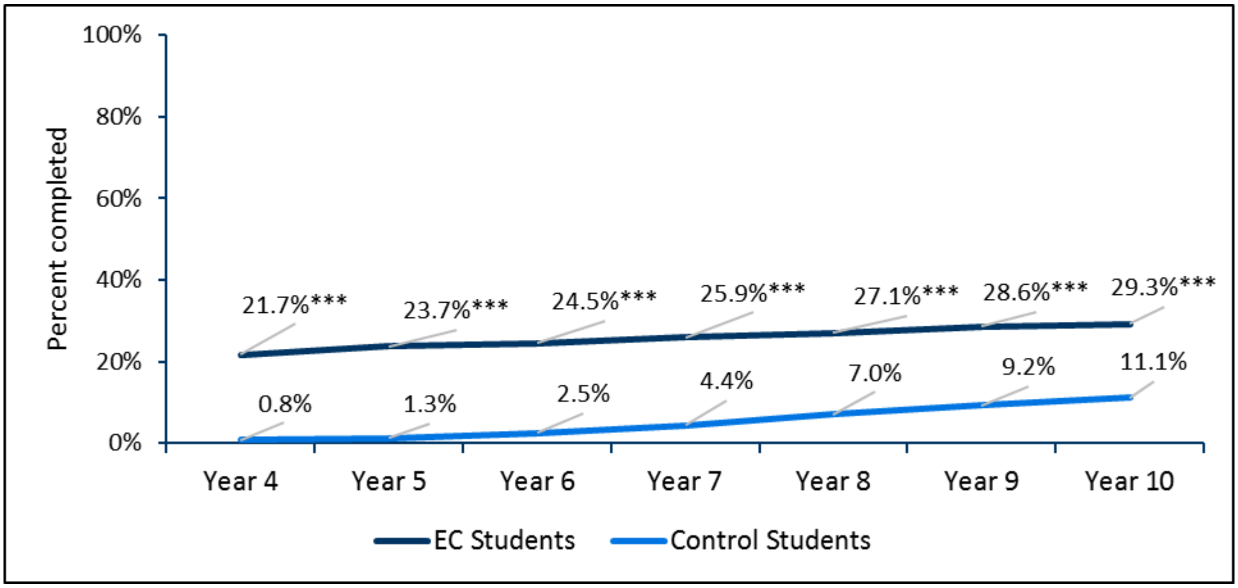
Exhibit 13. Percentage of Students Who Completed Any Postsecondary Degree Between Year 4 and Year 10, by Study Group



Notes. *N* = 2,458 (1,044 EC, 1,414 control). The percentages for EC students are unadjusted percentages; the percentages for control students were computed based on the unadjusted percentages for EC students and estimated EC effects.
Year x, x = 4~10, refers to x years after starting high school.
*** $p < .001$.

Regarding the completion of an associate's degree or certificate, the results presented in Exhibit 14 show that the differences between EC students and control students were largely stable in both size and statistical significance over time. By the end of the fourth year of high school, 21.7% of EC students and less than 1% of control students had completed an associate's degree or certificate ($p < .001$). EC-control differences in rates of associate's degree or certificate completion hovered between 20 and 22 percentage points and remained statistically significant through the final year of observation, 6 years after expected high school graduation, when the difference reduced slightly to 18.2 percentage points ($p < .001$).

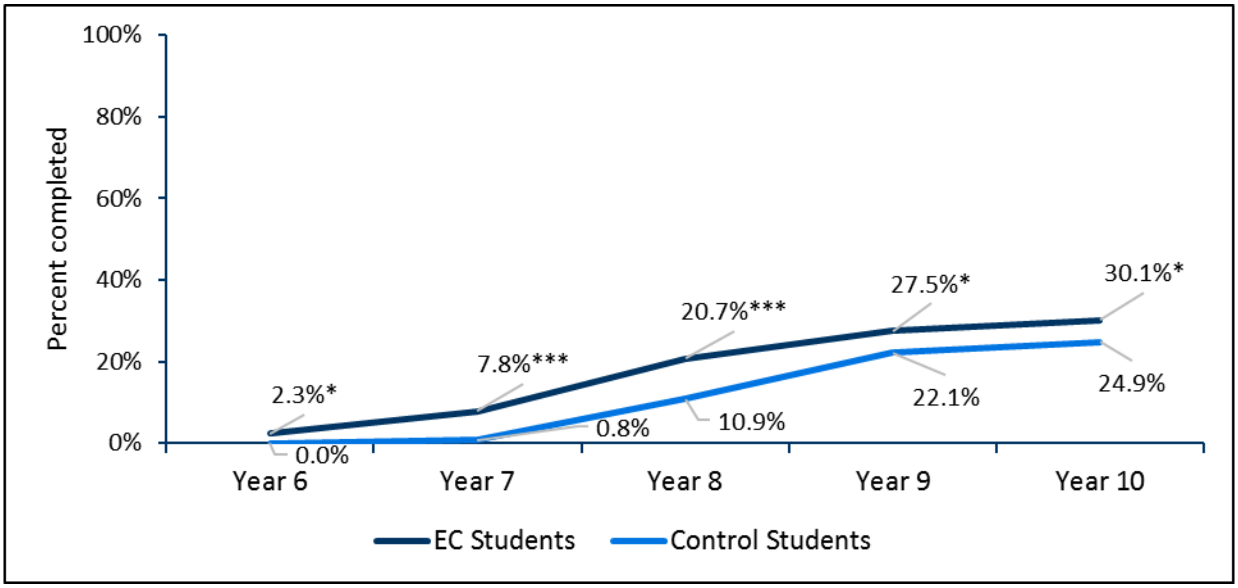
Exhibit 14. Percentage of Students Who Completed an Associate's Degree or Certificate Between Year 4 and Year 10, by Study Group



Notes. *N* = 2,458 (1,044 EC, 1,414 control). The percentages for EC students are unadjusted percentages; the percentages for control students were computed based on the unadjusted percentages for EC students and estimated EC effects.
Year x, x = 4~10, refers to x years after starting high school.
*** $p < .001$.

Where bachelor's degree completion is concerned, the difference between the two study groups first widened and then narrowed (but remained statistically significant) over the time frame we examined. As shown in Exhibit 15, by the end of Year 6, 2.3% of EC students and less than 1% of control students had completed a bachelor's degree, a difference of about 2 percentage points ($p < .05$). By the end of Year 8, which represents the fourth year after expected high school graduation, 20.7% of EC students completed a bachelor's degree, which was almost 10 percentage points higher than the rate for control students (10.9%; $p < .001$). This difference narrowed considerably—to 5.2 percentage points (30.1% of EC students and 24.9% control students)—by the end of Year 10 but remained statistically significant ($p < .05$). These findings again suggest that control students began to "catch up" to EC students over time in terms of bachelor's degree completion, but a significant difference between the two groups of students remained 6 years after expected high school graduation.

Exhibit 15. Percentage of Students Who Completed a Bachelor's Degree Between Year 4 and Year 10, by Study Group

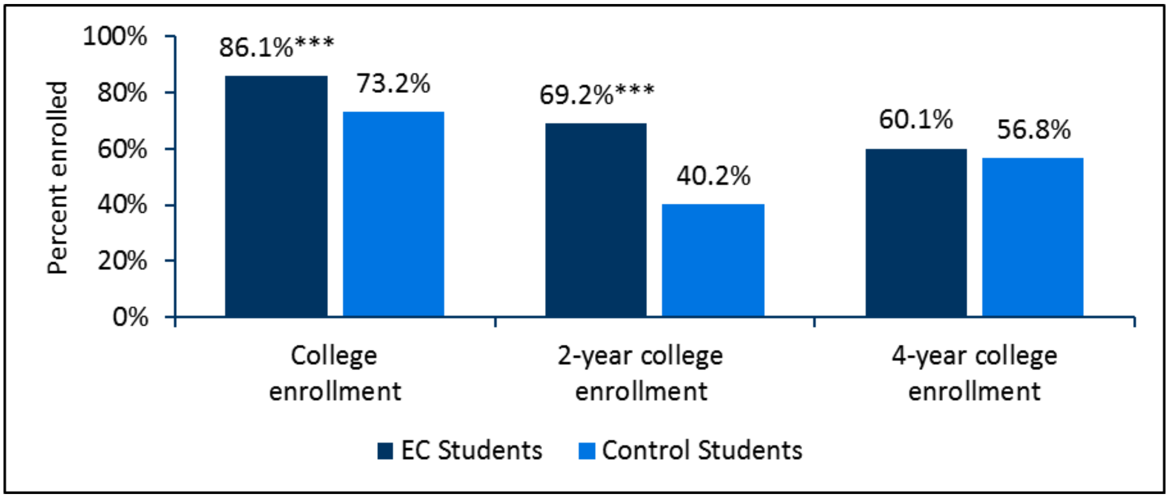


Notes. *N* = 2,458 (1,044 EC, 1,414 control). The percentages for EC students are unadjusted percentages; the percentages for control students were computed based on the unadjusted percentages for EC students and estimated EC effects.
Year x, x = 4~10, refers to x years after starting high school.
* $p < .05$; *** $p < .001$.

CATE Estimates for College Enrollment and Degree Attainment

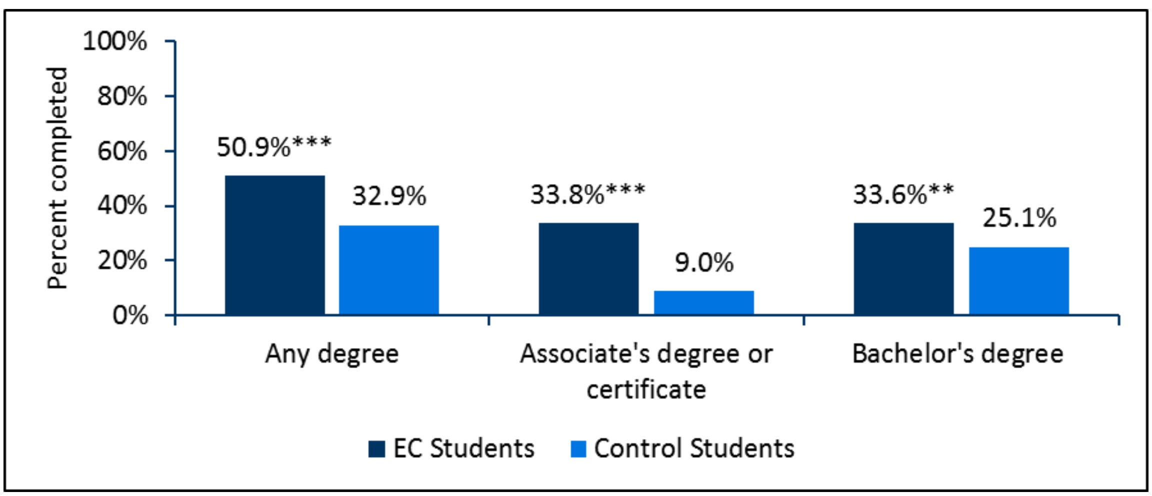
Because not all students who were selected for admission to an EC enrolled in the EC, ITT estimates of EC impacts are conservative in nature. To account for no-shows (i.e., treatment students who did not enroll in an EC) and crossovers (i.e., control students who somehow enrolled in an EC), we performed CATE analyses to supplement the ITT analyses (see Appendix D for technical details about the CATE analyses). Results from the CATE analyses mirror the results from the ITT analyses, with significant complier effects on all primary outcome measures in both the college enrollment domain (see Exhibit 16) and degree attainment domain (see Exhibit 17) except for enrollment in 4-year colleges. As expected, the CATE estimates tend to be larger than the ITT estimates of EC impact. For example, while the ITT estimate indicates an overall EC-control difference of approximately 5 percentage points in the probability of completing a bachelor's degree within 6 years after expected high school graduation (i.e., by Year 10), the CATE estimate indicates a group difference of 8.5 percentage points among compliers.

Exhibit 16. Percentage of Students Who Enrolled in College Within 6 Years After Expected High School Graduation Based on CATE Estimates, by Type of College and Study Group



Notes. N = 2,458 (1,044 EC, 1,414 control). The percentages for EC students are unadjusted percentages; the percentages for control students were computed based on the unadjusted percentages for EC students and estimated EC effects.
*** $p < .001$.

Exhibit 17. Percentage of Students Who Completed a College Degree Within 6 Years After Expected High School Graduation Based on CATE Estimates, by Type of Degree Completed and Study Group



Notes. *N* = 2,458 (1,044 EC, 1,414 control). The percentages for EC students are unadjusted percentages; the percentages for control students were computed based on the unadjusted percentages for EC students and estimated EC effects.
** $p < .01$; *** $p < .001$.

Sensitivity Analysis Results

In addition to the ITT and CATE analyses, we performed two sets of sensitivity analyses. First, we re-estimated EC impacts after removing the EC site where student demographic and prior achievement data had to be imputed for all EC and control students because their state did not allow us to link student background data to outcome data. Second, we re-estimated the EC impacts on primary college enrollment and degree attainment outcomes with a random-effects model, which allows the EC impact to vary across lotteries. The results of these sensitivity analyses are summarized below; see Appendix G for more details on these analyses.

Impact analyses excluding one EC with imputed background data for all students. Results from this set of analyses mirror the ITT results presented earlier with one exception: the EC impact on bachelor's degree completion within 6 years after expected high school graduation (i.e., by Year 10) was slightly smaller and only marginally significant (p = .096) after removing one site where background data were imputed for all students.

Impact analyses based on a random-effects model. Results from random-effects ITT analyses were largely consistent with the results from fixed-effects ITT analyses with one exception: the EC impact on bachelor's degree completion within 6 years after expected high school graduation (i.e., by Year 10), which was statistically significant (p < .05) based on the fixed-effects model, was somewhat smaller and no longer significant (p = .159) based on a random-effects model. In addition, we observed significant variation in impact estimates across lotteries for the outcomes of completing any type of degree and completing an associate's degree or certificate within 6 years after expected high school graduation (see Exhibit G-4 in Appendix G).

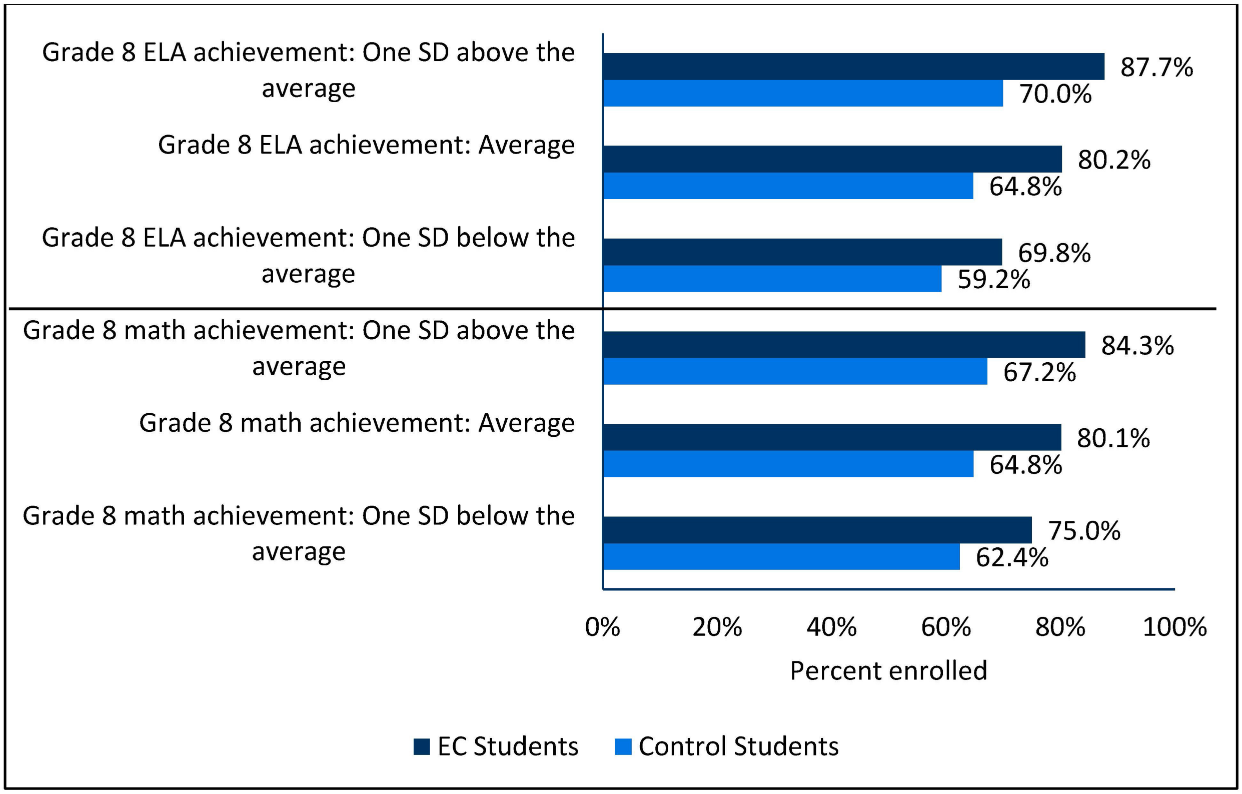
Differential EC Impacts on Student Outcomes (RQ2)

In this section, we present a summary of findings for RQ2: Did the impacts of ECs vary by student background characteristics? Detailed results are provided in Appendix F. Overall, we found that the EC impacts on college enrollment and degree attainment outcomes did not significantly differ by gender, race/ethnicity, or low-income status. However, we did find significant differential impacts based on students' Grade 8 achievement test scores.

Differential Impacts on College Enrollment

We found that the EC impact on enrolling in a 2-year college within 6 years after expected high school graduation (i.e., by Year 10) differed significantly by students' prior achievement in ELA (see Exhibit 18). The EC impact on enrolling in 2-year colleges was stronger for students with higher levels of Grade 8 ELA achievement than for students with lower levels of prior ELA achievement. The differential impact of ECs by students' Grade 8 mathematics achievement was similar in magnitude but only marginally significant (p < .10).

Exhibit 18. Percentage of Students Who Enrolled in a 2-Year College 6 Years After Expected High School Graduation, by Prior Achievement Level and Study Group

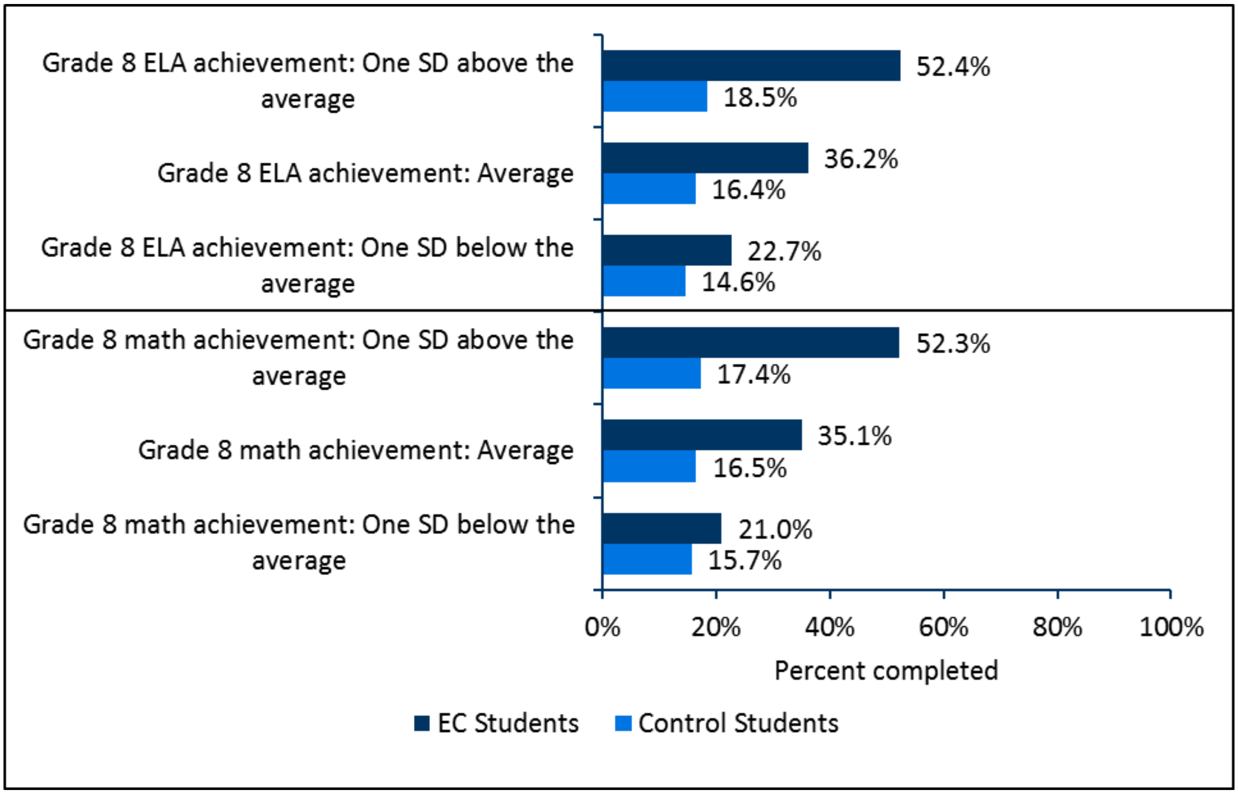


Notes. ELA = English language arts; SD = standard deviation. N = 2,458 (1,044 EC, 1,414 control). The treatment and control group percentages are predicted probabilities based on a differential impact model with grand-mean centered covariates other than prior achievement. Estimate of differential EC Impact by prior ELA achievement is significant at $p < .05$; estimate of differential EC impact by prior math achievement is marginally significant at $p < .10$.

Differential Impacts on Degree Attainment

We also found that the EC impact on completing an associate’s degree or certificate within 6 years after expected high school graduation differed by students’ prior achievement in both ELA and mathematics (see Exhibit 19). The impact on completing an associate’s degree or certificate was stronger for students with higher levels of Grade 8 achievement than for students with lower levels of prior achievement. We did not observe significant differential impacts on bachelor’s degree completion.

Exhibit 19. Percentage of Students Who Completed an Associate's Degree or Certificate 6 Years After Expected High School Graduation, by Prior Achievement Level and Study Group



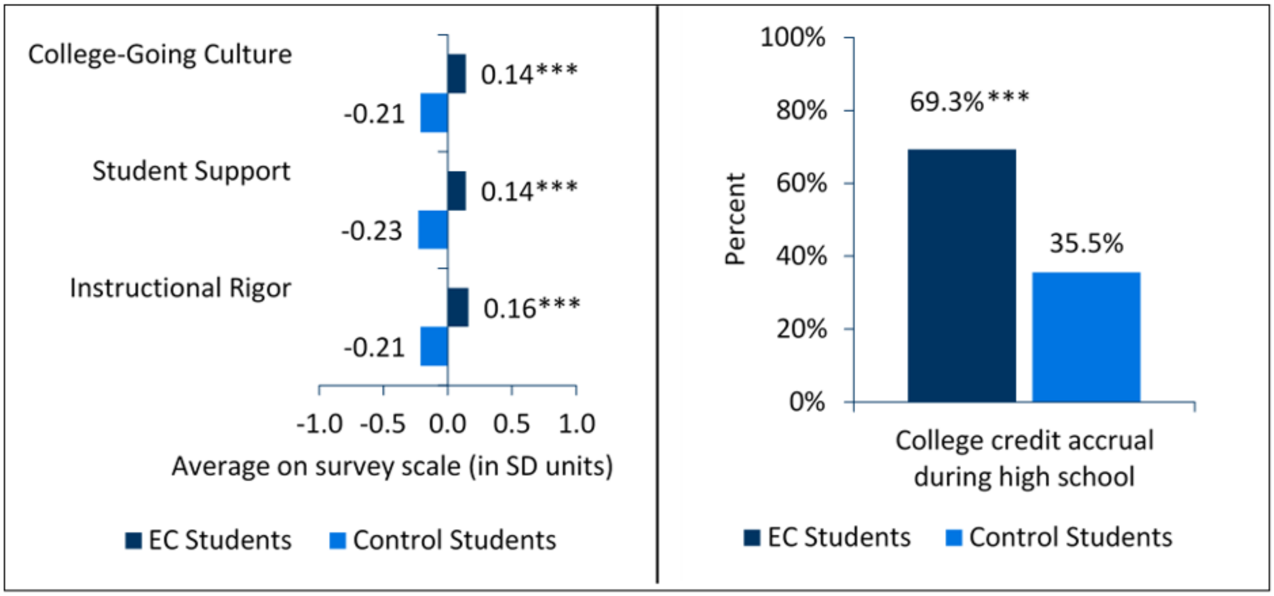
Notes. ELA = English language arts; SD = standard deviation. N = 2,458 (1,044 EC, 1,414 control). The treatment and control group percentages are predicted probabilities based on a differential impact model with grand-mean centered covariates other than prior achievement. Estimate of differential EC Impact by prior ELA achievement is significant at $p < .01$; estimate of differential EC impact by prior math achievement is significant at $p < .001$.

The Mediating Role of High School Experiences (RQ3)

To better understand EC impacts on student outcomes, we explored whether differences in students' experiences during high school explained observed differences in college enrollment and degree attainment outcomes 6 years after expected high school graduation. In this section, we first demonstrate EC impacts on students' high school experience as measured through a survey administered as part of the original impact study. We then present EC impacts on college enrollment and degree completion outcomes 6 years after expected high school graduation within our sample of survey respondents. Finally, for each primary outcome, we examine: (1) the percentage of the "total EC effect" that was explained by high school experience measures (i.e., indirect effect) and (2) the percentage of total EC effect not explained by high school experience measures (i.e., direct effect). (See Appendix D for technical details about the mediation analyses.)

As shown in Exhibit 20, EC students reported significantly more positive high school experiences than control students. For the measures of college-going culture, student support, and instructional rigor (see Exhibit 4 for details about these survey scales), the average scale scores for the EC students were approximately one third of a standard deviation higher than those for the control students. We also found that EC students were significantly more likely than control students to report college credit accrual during high school, which was measured as either earning college credit directly from college courses or passing at least one AP exam during high school. More than two thirds of EC students (69.3%) reported accruing college credit during high school, compared with about one third (35.5%) of the control students.

Exhibit 20. Average Scores on High School Experience Measures, by Study Group

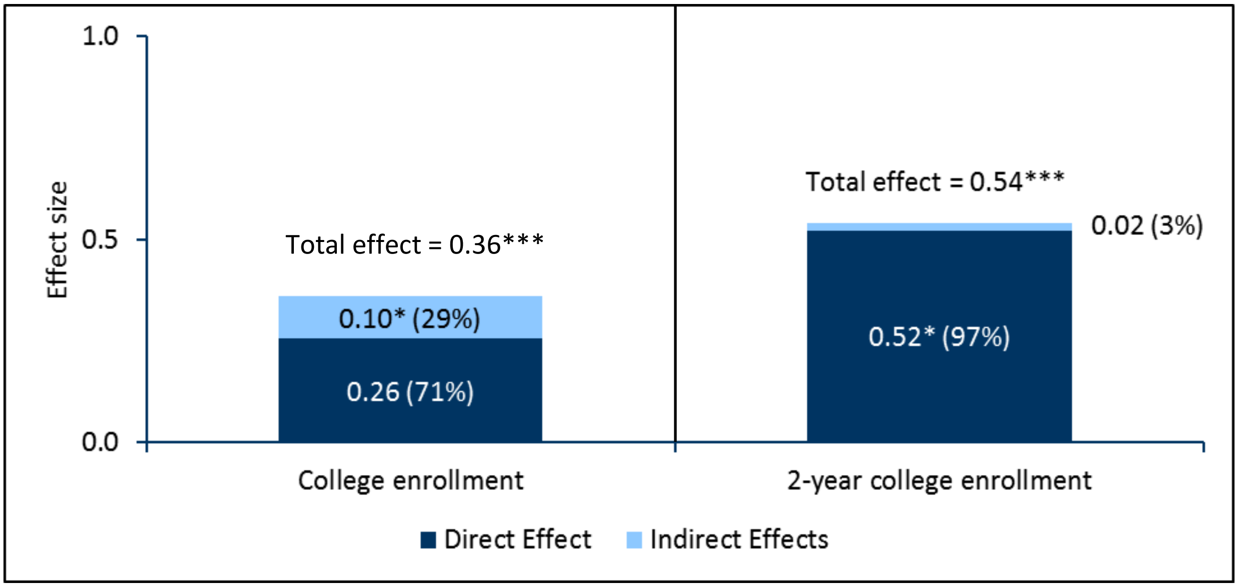


Notes. *N* = 1,424 (771 EC, 653 control). Survey scales of college-going culture, student support, and instructional rigor were standardized within the study sample to have a mean of 0 and a standard deviation (SD) of 1. The average scores for EC students are unadjusted score; the average scores for control students were computed based on the average scores for EC students and estimated EC effects.
*** $p < .001$.

Next, we examined EC impacts on college enrollment and degree completion outcomes among students who participated in the survey. Consistent with the impact findings based on the full sample, we found significant impacts on the college enrollment and degree completion outcomes for the survey participants with one exception: we did not observe a significant EC impact on enrollment in a 4-year college (see Exhibit F-8 in Appendix F for detailed results). Therefore, we did not include this outcome in mediation analyses. For the rest of the outcomes, the magnitude of the EC impact ranged from an effect size of 0.19 (for bachelor's degree completion) to 0.81 (for completing an associate's degree or certificate).

The results of our mediation analyses indicate that high school experiences explained a significant portion (29%) of the total EC effect on enrollment in any type of institution, but did not significantly explain the EC effect on enrollment in a 2-year college (see Exhibit 21). The direct EC effect on enrollment in a 2-year college accounted for 97% of the total EC effect and was statistically significant (*p* < .05).

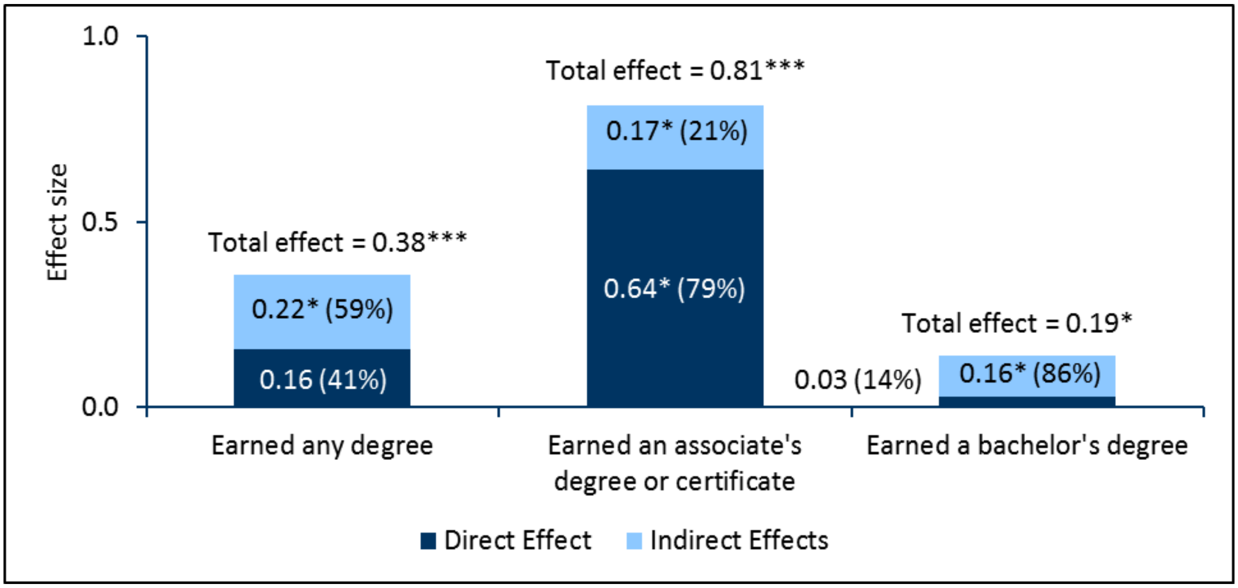
Exhibit 21. Total, Direct, and Indirect EC Effects on College Enrollment Among Students in the Student Survey Sample, 6 Years After Expected High School Graduation



Notes. N = 1,424 (771 EC, 653 control). The total effect is equal to the sum of the direct and the indirect effects. Direct and indirect effects were estimated with the following high school experience measures as mediators: instructional rigor, college-going culture, and student support.
**p* < .05; ****p* < .001.

High school experience measures appear to be stronger mediators for EC impacts on degree completion outcomes than for EC impacts on college enrollment outcomes. As shown in Exhibit 22, measures of high school experience explained 59% of the total EC effect on completing any type of degree, 21% of the EC effect on completing an associate's degree or certificate, and 86% of the EC effect on bachelor's degree completion (*p* < .05 for all three indirect effects). For each of these outcomes, detailed results showed that college credit accrual during high school explained the largest percentage of the total EC effect (see Exhibit F-9 in Appendix F). After accounting for high school experiences, the direct EC effect was statistically significant only for completing an associate's degree or certificate and no longer significant for overall degree completion or completing a bachelor's degree.

Exhibit 22. Total, Direct, and Indirect EC Effects on Degree Completion Among Students in the Student Survey Sample, 6 Years After Expected High School Graduation



Notes. N = 1,424 (771 EC, 653 control). The total effect is equal to the sum of the direct and the indirect effects. Direct and indirect effects were estimated with the following high school experience measures as mediators: instructional rigor, college-going culture, student support, and college credit accrual during high school.
**p* < .05; ****p* < .001.

Summary and Discussion

With additional years of data collected after the completion of the original EC impact study, this efficacy follow-up study assessed longer-term impacts of ECs on students' college enrollment and degree attainment outcomes as well as differential EC impacts based on student background characteristics. In addition, we explored the role of students' high school experiences in mediating the EC impacts on students' college enrollment and degree completion 6 years after expected high school graduation. Overall, the findings show positive EC impacts on various postsecondary outcomes over the time period examined in this study. These positive impacts were similarly observed for students from different family backgrounds, but some of the impacts were stronger for students with higher levels of Grade 8 achievement. Moreover, we found that while students' high school experiences had a limited role in mediating EC impacts on college enrollment outcomes, they accounted for significant portions of the EC impacts on degree completion outcomes. A more detailed summary of findings associated with each of the study's RQs is presented below.

EC Impacts on Students' Postsecondary Outcomes

RQ1: Did EC students have better postsecondary outcomes (i.e., college enrollment and degree attainment) than control students?

We found that EC students had a higher overall college enrollment rate and a higher 2-year college enrollment rate than control students by the end of each academic year between the fourth year of high school and 6 years after expected high school graduation. While we anticipated EC-control differences in college enrollment to occur during and immediately after high school (since ECs partner with postsecondary institutions to facilitate college credit accrual during high school), significant EC-control differences in enrollment in 2-year colleges persisted for at least 6 years after expected high school graduation. By the end of Year 10 after starting high school, approximately two thirds (65.8%) of EC students enrolled in 2-year colleges, compared with fewer than half (46.8%) of control students ($p < .001$). Therefore, control students did not catch up with EC students in terms of enrollment in 2-year colleges over the extended time period examined in this study.

In contrast, we did not observe significant EC impacts on enrollment in 4-year colleges, or selective 4-year colleges, after the second year after expected high school graduation. Although we observed significant differences between EC students and control students in the rates of enrolling in 4-year colleges and selective 4-year colleges during high school, control students caught up over time such that, 6 years after expected high school graduation, similar percentages of EC students (57.6%) and control students (56.7%) had enrolled in 4-year colleges, and about the same percentage of students in both groups (17.8% for EC and 17.7% for control) had enrolled in selective 4-year colleges.

Because eight of the 10 ECs in our study partnered with 2-year colleges, one might anticipate that EC students would be more likely to enroll in 2-year colleges and less likely to enroll in 4-year colleges than control students. Examination of enrollment profiles over time confirmed that EC students were more likely to enroll exclusively in 2-year colleges and more likely to transfer from 2-year colleges to 4-year colleges than control students, whereas control students were more likely to directly enroll in 4-year colleges than EC students. In fact, by the first year after expected high school graduation, almost one quarter (24.8%) of EC students and only 5.5% of control students had transferred from 2-year to 4-year colleges, while the percentage of students who had enrolled immediately in 4-year colleges was almost twice as high among control students (46.3%) than among EC students (24.3%).

We also observed that EC impacts on college enrollment translated into significant differences in degree completion outcomes between EC students and control students. Within 6 years after expected high school graduation (i.e., by Year 10), 45.4% of EC students—compared with 33.5% of control students—completed a postsecondary degree ($p < .001$). Significant impacts were also observed both for completion of an associate's degree or certificate (29.3% of EC students and 11.1% of control students) and bachelor's degree completion (30.1% of EC students and 24.9% of control students) within 6 years after expected high school graduation. Of particular note is that we observed a significant, positive EC impact on bachelor's degree completion 6 years after expected high school graduation despite the fact that we did not observe a significant impact on enrollment in 4-year colleges, perhaps suggesting that EC students were better *prepared* for their education at 4-year colleges, or that they were able to complete the degree *faster* (within 6 years after expected high school graduation) because of their early exposure to college during high school. Although most of the ECs in our study partnered with 2-year colleges, it appears that EC students' experiences with these colleges supported their pursuit and completion of bachelor's degrees.

Finally, we found that EC students were more likely to complete bachelor's degrees *more quickly* than control students, which has implications for potential lifetime earnings. While the EC-control difference in bachelor's degree completion rates amounted to about five percentage points 6 years after expected high school graduation, it was about 10 percentage points 4 years after expected high school graduation (by which time 20.7% of EC students and 10.9% of control students completed a bachelor's degree). Therefore, while the difference in bachelor's degree completion narrowed over time, the fact remains that a larger percentage of EC students completed bachelor's degrees earlier in their lives, allowing them to either get a head start on furthering their education or entering the labor force with this credential at a younger age.

Differential EC Impacts

RQ2: Did the impacts of ECs vary by student background characteristics (i.e., gender, race/ethnicity, low-income status, and prior mathematics and ELA achievement)?

Similar to findings from the original EC impact study (Haxton et al., 2016), we found that EC impacts on primary postsecondary outcomes did not vary significantly by gender, race/ethnicity, or low-income status, but impacts on some outcomes did vary for students with different levels of prior achievement. Specifically, we found that the EC impact on enrollment in 2-year colleges was significantly stronger for students with higher levels of Grade 8 ELA achievement, and the EC impact on completion of an associate's degree or certificate was significantly stronger for students with higher levels of Grade 8 ELA or mathematics achievement. One possible explanation is that, because most of the ECs in our study partnered with 2-year colleges, higher-achieving students in ECs might have been more likely to enroll in

2-year colleges (and subsequently complete an associate's degree or certificate) during or immediately after high school relative to higher-achieving students in the control group who may have entered directly into a 4-year college after graduating from high school. We did not observe significant differential impacts on enrollment in 4-year colleges or completion of a bachelor's degree by levels of prior achievement, indicating that starting at a 2-year college did not prevent higher-achieving EC students from pursuing a 4-year college degree.

The Mediating Role of High School Experiences

RQ3: Were the impacts of ECs mediated by students' high school experiences (i.e., college credit accrual during high school, instructional rigor, college-going culture, and student supports)?

Our mediation analyses revealed that students' high school experiences accounted for a significant portion (29%) of the total EC impact on college enrollment, but did not significantly explain the EC impact on enrollment in 2-year colleges within 6 years after expected high school graduation. For EC impacts on degree completion outcomes, students' high school experiences played a stronger mediating role, explaining 59% of the total EC impact on completing any type of degree, 21% of the EC impact on completing an associate's degree or certificate, and 86% of the EC impact on bachelor's degree completion 6 years after expected high school graduation. Among measures of students' high school experiences, college credit accrual during high school explained the largest percentage of the EC impacts on degree completion outcomes, highlighting the importance of college credit accrual during high school for college degree completion.

Caveats and Future Research

The primary goal for this study was to assess the degree to which ECs improved students' postsecondary outcomes. Such a question could theoretically be answered by randomly assigning students to treatment and control conditions at a randomly selected set of ECs across the country. Under this ideal situation, we would be able to estimate impacts that would generalize to over 200 ECs that currently operate nationwide. Such a study, however, is not feasible because many districts, schools, and parents would not allow students to be randomly assigned to specific high schools. In addition, to assess EC impacts on longer-term outcomes (e.g., bachelor's degree completion) that are of particular interest to this study, relevant data would need to be collected at least 8 years after random assignment, which would be well beyond the timeframe for typical impact studies in education.

Randomization of students through lottery-based admissions offered us the opportunity to draw valid causal conclusions about the impacts of ECs on student outcomes, including longer-term outcomes, in a timely manner. The drawback, however, is that the estimated impacts only apply to the 10 ECs that participated in our study. Not all ECs use lotteries to determine admissions, and the decision about whether to use an admissions lottery is itself not random. To offer a lottery, a school must have more applicants than it has seats available and must further use a random assignment process for admissions.[16] In addition, to be eligible for inclusion in a retrospective study such as ours, ECs that used an admissions lottery must also be able to provide lottery records to verify that random assignment occurred and to allow the study team to identify the treatment and control students among lottery participants. Therefore, as with any study relying on retrospective admissions lotteries, our study includes a nonrandom set of ECs, limiting the generalizability of study findings.

Further, given the retrospective nature of the study, the results of our study may not apply to students who currently attend these ECs. Students in our sample entered Grade 9 between 2005–06 and 2007–08, and many aspects of the ECs themselves such as staff and administration, partnership between the EC and the postsecondary institution, and admissions processes may have changed over time. In addition, changes in education policies at the local, state, and national levels have brought increased focus on college and career readiness for all students, including those who do not attend ECs. Therefore, while this study provides a rigorous assessment of the longer-term impacts of ECs on students who entered ECs over a decade ago, continued research will be necessary to determine whether positive impacts also occur for the current generation of EC students.

Another limitation of the study is related to the characteristics of the student participants. While over half of the students in the study sample were racial minority students and almost half of the students were from low-income families—reflecting the ECHSI's commitment to serving students from underrepresented populations—the students in our study sample were more academically prepared than typical students in their districts. On average, students in our study had Grade 8 test scores that were approximately 0.2 standard deviations above the state average. Therefore, it is important to note that the students in our study sample were not representative of the population of underrepresented students in their state.

Because of these limitations, the study findings may not be generalizable to ECs or students outside of the study sample. However, the set of ECs in this study offered us the unique opportunity to compare the outcomes of students who were randomly selected to attend an EC through a lottery with the outcomes of students who did not win the lottery but would have

[16] Although one may assume that only selective, high-performing high schools would have the opportunity to initiate a lottery system due to oversubscription, this was not always the case. In fact, some of the ECs in this study implemented admission lotteries due to local or state education policies or citywide high school application processes.

otherwise attended the same EC. Thus, despite its limited external validity, this study has strong internal validity built upon a rigorous "gold standard" randomized experimental design.

One avenue for future research is a focus on more recent cohorts of EC students from a more representative sample of ECs. Findings from such research would determine whether the positive EC impacts we observed within our sample of ECs apply to the larger population of ECs, and how these impacts may have changed over time as the characteristics of the ECs (as well as the opportunities available to students who do not attend ECs) have changed over time.

Another area in need of future research is EC impacts on longer-term outcomes related to students' employment and earnings. It is likely that the higher rates and earlier timing of degree completion for EC students would lead to better labor market outcomes (e.g., employment, career advancement and income) for these students in the long run. In addition, we hypothesize that, because EC students were more likely to receive college credit during high school at little or no cost to their families, EC students would be less likely to accrue student loan debt than control students. Until we have collected information on students' workforce and financial outcomes, we can only conjecture about these longer-term impacts.

Finally, the small number of sites in this study limited our ability to explore potential variation in EC impacts across sites. Future research on EC impacts that includes a larger number of sites could examine both variations in EC impacts and factors that may be associated with such variations. Such research could inform several policy- and practice-relevant questions: Which supports most strongly relate to EC impacts on students' postsecondary outcomes? Can traditional high schools leverage current dual enrollment policies and include EC components to improve student access to and success in college? What is the role of state policy in the success of ECs? These additional lines of future research on ECs will generate valuable insights that will inform policies and practices pertaining to the implementation and scale-up of ECs as a promising dual enrollment model with proven impact on students' postsecondary success.

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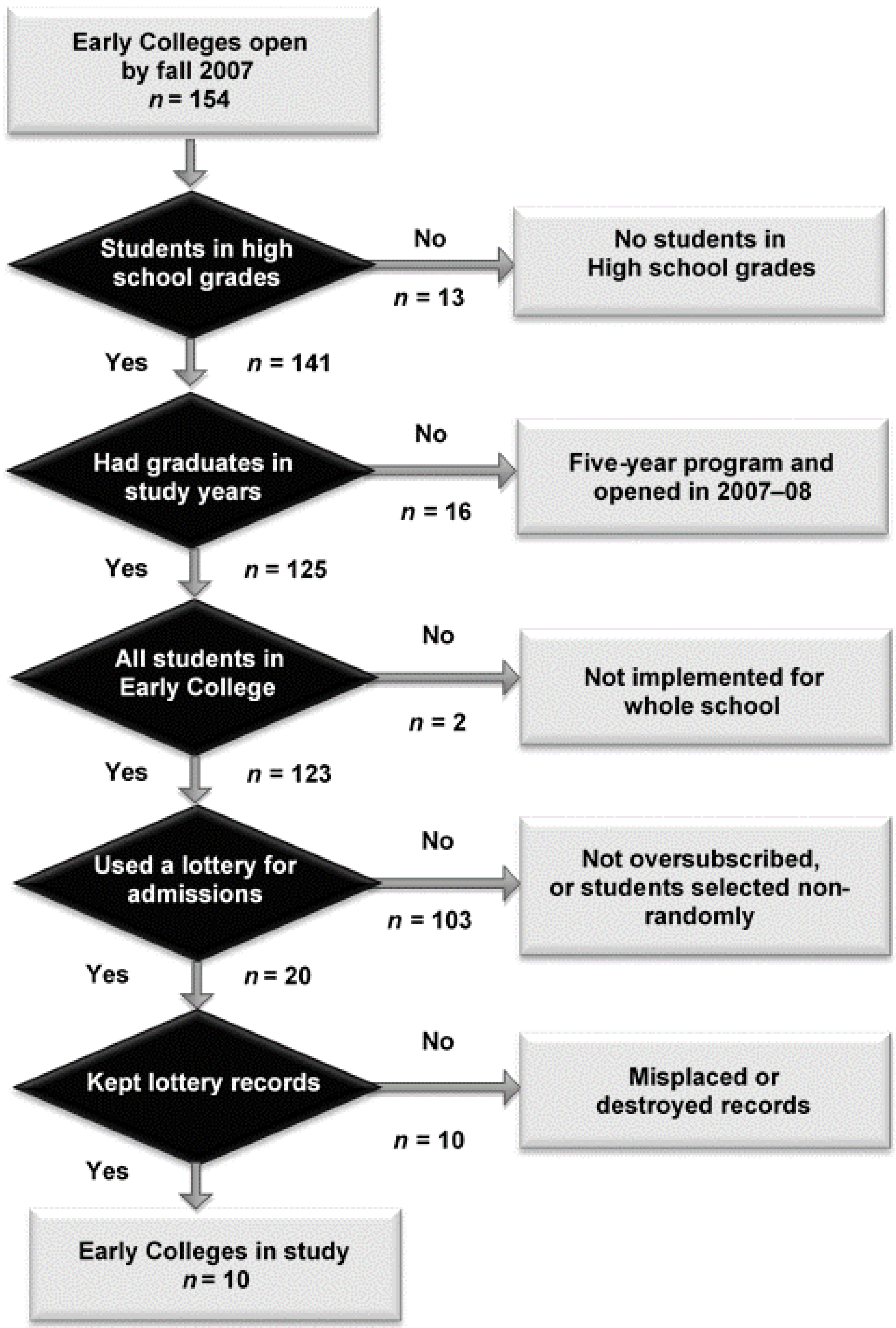
Appendix A. Flowchart for Identifying ECs for the Original Impact Study



Appendix B. Sample Size by School and Cohort

Exhibit B-1. Number of Treatment and Control Students in Each Lottery and Sublottery in the Full Sample of the Impact Study, by Study School and Cohort

Study Schools	Ninth-Grade Student Cohort							
	Cohort 1 (2005–06)		Cohort 2 (2006–07)		Cohort 3 (2007–08)		Total	
	Treatment	Control	Treatment	Control	Treatment	Control	Treatment	Control
School A			27	43			27	43
School B			85	103	87	54	172	157
School C	30	282	71	231	69	257	170	770
School D								
• Lottery 1			99	10	83	28	182	38
• Lottery 2			7	3	2	10	9	13
School E	62	24					62	24
• Lottery 1					8	4	8	4
• Lottery 2					7	7	7	7
• Lottery 3					6	7	6	7
School F			51	39	57	64	108	103
School G					124	74	124	74
School H			52	91			52	91
School I	41	37	39	31			80	68
School J								
• Lottery 1					3	3	3	3
• Lottery 2					4	3	4	3
• Lottery 3					30	9	30	9
Total	**133**	**343**	**431**	**551**	**480**	**520**	**1,044**	**1,414**

*Note*s. The total sample size across the 23 lotteries (including sublotteries) was 2,458 students (1,044 treatment and 1,414 control students). Shaded cells represent years that the school (1) was not yet open, (2) did not have a lottery, (3) did not have lottery records, or (4) did not have a graduating student cohort during the study period. Schools D, E, and J each had sublotteries for at least one student cohort.

Exhibit B-2. Number of Treatment and Control Students in Each Lottery in the Survey Sample of the Impact Study, by Study School and Cohort

Study Schools	Ninth-Grade Student Cohort					
	Cohort 2 (2006–07)		Cohort 3 (2007–08)		Total	
	Treatment	Control	Treatment	Control	Treatment	Control
School A	27	43			27	43
School B	75	93	87	54	162	147
School C	71	101	69	98	140	199
School D	91	10	83	28	174	38
School E						
• Lottery 1			8	4	8	4
• Lottery 2			7	7	7	7
• Lottery 3			6	7	6	7
School F	51	39	57	64	108	103
School G			100	74	100	74
School I	39	31			39	31
Total	**354**	**317**	**417**	**336**	**771**	**653**

Notes. Total sample size across lotteries = 1,424 students (771 treatment and 653 control students). Shaded cells are years that the school (1) was not yet open, (2) did not have a lottery, (3) did not have lottery records, or (4) did not have a graduating student cohort during the study period. School E had three sublotteries for the ninth-grade student cohort in 2007–08.

Appendix C. Outcome Measures

In this appendix, we list and define the outcome measures we examined for the efficacy follow-up study of EC high schools.

Exhibit C-1. College Enrollment Outcomes

Measure	Description
Primary College Enrollment Outcomes	
Enrolled in college by Year 10	Dichotomous indicator of whether a student ever enrolled in college by the end of August of Year 10 after starting Grade 9 (i.e., within 6 years after expected high school graduation)
Enrolled in a 2-year college by Year 10	Dichotomous indicator of whether a student ever enrolled in a 2-year college by the end of August of Year 10 after starting Grade 9 (i.e., within 6 years after expected high school graduation)
Enrolled in a 4-year college by Year 10	Dichotomous indicator of whether a student ever enrolled in a 4-year college by the end of August of Year 10 after starting Grade 9 (i.e., within 6 years after expected high school graduation)
Additional College Enrollment Outcomes	
Enrolled in college by Year 4	Dichotomous indicator of whether a student ever enrolled in college by the end of August of Year 4 after starting Grade 9
Enrolled in college by Year 5	Dichotomous indicator of whether a student ever enrolled in college by the end of August of Year 5 after starting Grade 9
Enrolled in college by Year 6	Dichotomous indicator of whether a student ever enrolled in college by the end of August of Year 6 after starting Grade 9
Enrolled in college by Year 7	Dichotomous indicator of whether a student ever enrolled in college by the end of August of Year 7 after starting Grade 9
Enrolled in college by Year 8	Dichotomous indicator of whether a student ever enrolled in college by the end of August of Year 8 after starting Grade 9
Enrolled in college by Year 9	Dichotomous indicator of whether a student ever enrolled in college by the end of August of Year 9 after starting Grade 9
Enrolled in a 2-year college by Year 4	Dichotomous indicator of whether a student ever enrolled in a 2-year college by the end of August of Year 4 after starting Grade 9
Enrolled in a 2-year college by Year 5	Dichotomous indicator of whether a student ever enrolled in a 2-year college by the end of August of Year 5 after starting Grade 9
Enrolled in a 2-year college by Year 6	Dichotomous indicator of whether a student ever enrolled in a 2-year college by the end of August of Year 6 after starting Grade 9

Measure	Description
Enrolled in a 2-year college by Year 7	Dichotomous indicator of whether a student ever enrolled in a 2-year college by the end of August of Year 7 after starting Grade 9
Enrolled in a 2-year college by Year 8	Dichotomous indicator of whether a student ever enrolled in a 2-year college by the end of August of Year 8 after starting Grade 9
Enrolled in a 2-year college by Year 9	Dichotomous indicator of whether a student ever enrolled in a 2-year college by the end of August of Year 9 after starting Grade 9
Enrolled in a 4-year college by Year 4	Dichotomous indicator of whether a student ever enrolled in a 4-year college by the end of August of Year 4 after starting Grade 9
Enrolled in a 4-year college by Year 5	Dichotomous indicator of whether a student ever enrolled in a 4-year college by the end of August of Year 5 after starting Grade 9
Enrolled in a 4-year college by Year 6	Dichotomous indicator of whether a student ever enrolled in a 4-year college by the end of August of Year 6 after starting Grade 9
Enrolled in a 4-year college by Year 7	Dichotomous indicator of whether a student ever enrolled in a 4-year college by the end of August of Year 7 after starting Grade 9
Enrolled in a 4-year college by Year 8	Dichotomous indicator of whether a student ever enrolled in a 4-year college by the end of August of Year 8 after starting Grade 9
Enrolled in a 4-year college by Year 9	Dichotomous indicator of whether a student ever enrolled in a 4-year college by the end of August of Year 9 after starting Grade 9
Enrolled in a selective 4-year college by Year 4	Dichotomous indicator of whether a student ever enrolled in a selective 4-year college (as defined by *Barron's Profiles of American Colleges*) by the end of August of Year 4 after starting Grade 9
Enrolled in a selective 4-year college by Year 5	Dichotomous indicator of whether a student ever enrolled in a selective 4-year college (as defined by *Barron's Profiles of American Colleges*) by the end of August of Year 5 after starting Grade 9
Enrolled in a selective 4-year college by Year 6	Dichotomous indicator of whether a student ever enrolled in a selective 4-year college (as defined by *Barron's Profiles of American Colleges*) by the end of August of Year 6 after starting Grade 9
Enrolled in a selective 4-year college by Year 7	Dichotomous indicator of whether a student ever enrolled in a selective 4-year college (as defined by *Barron's Profiles of American Colleges*) by the end of August of Year 7 after starting Grade 9
Enrolled in a selective 4-year college by Year 8	Dichotomous indicator of whether a student ever enrolled in a selective 4-year college (as defined by *Barron's Profiles of American Colleges*) by the end of August of Year 8 after starting Grade 9
Enrolled in a selective 4-year college by Year 9	Dichotomous indicator of whether a student ever enrolled in a selective 4-year college (as defined by *Barron's Profiles of American Colleges*) by the end of August of Year 9 after starting Grade 9

Measure	Description
Enrolled in a selective 4-year college by Year 10	Dichotomous indicator of whether a student ever enrolled in a selective 4-year college (as defined by *Barron's Profiles of American Colleges*) by the end of August of Year 10 after starting Grade 9
Enrollment profile by Year 5	Categorical variable indicating whether a student had (1) not enrolled in college, (2) ever enrolled exclusively in 2-year colleges, (3) ever enrolled in a 4-year college with a prior enrollment in a 2-year college, or (4) ever enrolled in a 4-year college without a prior enrollment in a 2-year college by the end of August of Year 5 after starting Grade 9
Enrollment profile by Year 6	Categorical variable indicating whether a student had (1) not enrolled in college, (2) ever enrolled exclusively in 2-year colleges, (3) ever enrolled in a 4-year college with a prior enrollment in a 2-year college, or (4) ever enrolled in a 4-year college without a prior enrollment in a 2-year college by the end of August of Year 6 after starting Grade 9
Enrollment profile by Year 7	Categorical variable indicating whether a student had (1) not enrolled in college, (2) ever enrolled exclusively in 2-year colleges, (3) ever enrolled in a 4-year college with a prior enrollment in a 2-year college, or (4) ever enrolled in a 4-year college without a prior enrollment in a 2-year college by the end of August of Year 7 after starting Grade 9
Enrollment profile by Year 8	Categorical variable indicating whether a student had (1) not enrolled in college, (2) ever enrolled exclusively in 2-year colleges, (3) ever enrolled in a 4-year college with a prior enrollment in a 2-year college, or (4) ever enrolled in a 4-year college without a prior enrollment in a 2-year college by the end of August of Year 8 after starting Grade 9
Enrollment profile by Year 9	Categorical variable indicating whether a student had (1) not enrolled in college, (2) ever enrolled exclusively in 2-year colleges, (3) ever enrolled in a 4-year college with a prior enrollment in a 2-year college, or (4) ever enrolled in a 4-year college without a prior enrollment in a 2-year college by the end of August of Year 9 after starting Grade 9
Enrollment profile by Year 10	Categorical variable indicating whether a student had (1) not enrolled in college, (2) ever enrolled exclusively in 2-year colleges, (3) ever enrolled in a 4-year college with a prior enrollment in a 2-year college, or (4) ever enrolled in a 4-year college without a prior enrollment in a 2-year college by the end of August of Year 10 after starting Grade 9

Exhibit C-2. Degree Attainment Outcomes

Measure	Description
Primary Degree Attainment Outcomes	
Completed any postsecondary degree by Year 10	Dichotomous indicator of whether a student ever received any type of postsecondary credential, including a certificate, an associate's degree, or a bachelor's degree, by the end of August of Year 10 after starting Grade 9 (i.e., within 6 years after expected high school graduation)
Completed an associate's degree or certificate by Year 10	Dichotomous indicator of whether a student ever received an associate's degree or a postsecondary certificate by the end of August of Year 10 after starting Grade 9 (i.e., within 6 years after expected high school graduation)
Completed a bachelor's degree by Year 10	Dichotomous indicator of whether a student ever received a bachelor's degree by the end of August of Year 10 after starting Grade 9 (i.e., within 6 years after expected high school graduation, or 150% of expected time to completion)
Additional Degree Attainment Outcomes	
Completed a postsecondary degree by Year 4	Dichotomous indicator of whether a student received any postsecondary degree by the end of August of Year 4 after starting Grade 9
Completed a postsecondary degree by Year 5	Dichotomous indicator of whether a student received any postsecondary degree by the end of August of Year 5 after starting Grade 9
Completed a postsecondary degree by Year 6	Dichotomous indicator of whether a student received any postsecondary degree by the end of August of Year 6 after starting Grade 9
Completed a postsecondary degree by Year 7	Dichotomous indicator of whether a student received any postsecondary degree by the end of August of Year 7 after starting Grade 9
Completed a postsecondary degree by Year 8	Dichotomous indicator of whether a student received any postsecondary degree by the end of August of Year 8 after starting Grade 9
Completed a postsecondary degree by Year 9	Dichotomous indicator of whether a student received any postsecondary degree by the end of August of Year 9 after starting Grade 9
Completed an associate's degree or certificate by Year 4	Dichotomous indicator of whether a student received an associate's degree or a postsecondary certificate by the end of August of Year 4 after starting Grade 9

Measure	Description
Completed an associate’s degree or certificate by Year 5	Dichotomous indicator of whether a student received an associate’s degree or a postsecondary certificate by the end of August of Year 5 after starting Grade 9
Completed an associate’s degree or certificate by Year 6	Dichotomous indicator of whether a student received an associate’s degree or a postsecondary certificate by the end of August of Year 6 after starting Grade 9
Completed an associate’s degree or certificate by Year 7	Dichotomous indicator of whether a student received an associate’s degree or a postsecondary certificate by the end of August of Year 7 after starting Grade 9 (i.e., within 3 years after expected high school graduation, or 150% of expected time to completion)
Completed an associate’s degree or certificate by Year 8	Dichotomous indicator of whether a student received an associate’s degree or a postsecondary certificate by the end of August of Year 8 after starting Grade 9
Completed an associate’s degree or certificate by Year 9	Dichotomous indicator of whether a student received an associate’s degree or a postsecondary certificate by the end of August of Year 9 after starting Grade 9
Completed a bachelor’s degree by Year 6	Dichotomous indicator of whether a student received a bachelor’s degree by the end of August of Year 6 after starting Grade 9
Completed a bachelor’s degree by Year 7	Dichotomous indicator of whether a student received a bachelor’s degree by the end of August of Year 7 after starting Grade 9
Completed a bachelor’s degree by Year 8	Dichotomous indicator of whether a student received a bachelor’s degree by the end of August of Year 8 after starting Grade 9
Completed a bachelor’s degree by Year 9	Dichotomous indicator of whether a student received a bachelor’s degree by the end of August of Year 9 after starting Grade 9

Appendix D. Technical Details on Analytic Methods

In this appendix, we provide a detailed description of the ITT, CATE, and mediation analyses we performed for the efficacy follow-up study of EC high schools.

ITT Analyses

Our main impact analyses are ITT analyses, which estimate the impact of being offered admission to an EC through a lottery, regardless of whether the student actually enrolled in the EC. To estimate the overall ITT effects on binary postsecondary outcomes across lotteries, we constructed a two-level model that takes into account the clustering of students within lotteries. The treatment indicator was group-mean centered at the student level to make sure the comparisons of EC students and control students were made *within* rather than *across* lotteries, and thus produced unbiased estimates (Enders & Tofighi, 2007; Raudenbush, 1989). We modeled the intercept as a random effect to take into account the clustering of student outcomes within lotteries. We modeled the treatment effect as fixed at the lottery level because the number of lotteries in the study was too small to generate stable estimates of the variation in treatment effects across lotteries.

Compared with a random-effects model with both a random intercept and a random treatment slope at the lottery level, our fixed-effects model is associated with greater statistical power, but it does not allow us to generalize study findings to EC admission lotteries beyond those in the study sample or to examine the variation in EC impact across lotteries. An alternative specification of the fixed-effects model is a student-level regression with a treatment indicator and lottery fixed effects. Such a model, however, suffers from the “complete separation” problem for certain binary outcomes in our study because, in some lotteries, 100% of the students experienced the outcome, or 100% of the students did not experience the outcome, which would lead to the exclusion of such lotteries from the impact estimation.

Below is the specification of the random intercept, fixed-slope hierarchical generalized linear model that we used to assess the EC impacts on binary postsecondary outcomes:

Level-1 Model (Student Level):

$$\log[\phi_{ij}/(1-\phi_{ij})] = \beta_{0j} + \beta_{1j}{}^{*}EC_{ij} + \beta_{2j}{}^{*}X_{ij} + \sum_{m=2}^{m}(\beta_{3mj} * SUBLOT_{mij}) \qquad (1)$$

where

- ϕ_{ij} is the probability of experiencing the outcome (e.g., enrolling in college by the end of Year 10) for student *i* in lottery *j*;

- EC_{ij} is a dummy indicator for treatment status (coded 1 if the student won the EC lottery and 0 otherwise, centered on the lottery mean);
- X_{ij} is a vector of student characteristics, grand-mean centered;
- $SUBLOT_{mij}$ is a set of effect-coded indicators for the *m* sublotteries within a lottery with multiple sublotteries.[17]
- β_{0j} is the average outcome (in logits) among control students in lottery *j*;
- β_{1j} is the difference in the average outcome between EC students and control students in lottery *j*;
- β_{2j} is the relationship between student characteristic *X* and the outcome in lottery *j*;
- β_{3mj} is the difference in the average outcome between control students in sublottery *m* and control students across all sublotteries in the given lottery with sublotteries.

Level-2 Model (Lottery Level):

$$\beta_{0j} = \gamma_{00} + u_{0j} \quad (2)$$

$$\beta_{1j} = \gamma_{10} \quad (3)$$

$$\beta_{2j} = \gamma_{20} \quad (4)$$

$$\beta_{3mj} = \gamma_{3m0} \quad (5)$$

where

- γ_{00} is the average outcome (in logits) among control students across all lotteries;
- γ_{10} is the average difference in the outcome between EC students and control students across all lotteries;
- γ_{20} is the average relationship between student characteristic *X* and the outcome across all lotteries;
- γ_{3m0} is the difference between the average outcome for control students in sublottery *m* and the average outcome for control students across all sublotteries in the given lottery with sublotteries; and
- u_{0j} is a random error associated with lottery *j*.

[17] For a given lottery with *m* sublotteries, $SUBLOT_{mij}$ was coded -1 for students in the omitted reference sublottery (i.e., if *m* = 1), 1 for students in sublottery *m* within the given lottery, and 0 for all other students. Given the effect coding, the treatment effect for such a lottery represents the equally weighted effect across the *m* sublotteries within the lottery. There is one set of sublottery indicators for each lottery with sublotteries in the level-1 equation, although only one set is shown for simplicity.

The estimate of primary interest from the model is γ_{10} at the lottery level, which represents a precision-weighted overall treatment effect across all lotteries in the study sample, with larger weights for lotteries with more students. For these models, the treatment effect was estimated in the logged odds ratio (logit) metric, where odds were defined as the probability of experiencing the outcome (e.g., enrolling in a 4-year college) divided by the probability of not experiencing the outcome. To facilitate the interpretation of the size of the treatment effects on binary outcomes, we converted the effect estimates into effect sizes using the Cox index (i.e., logged odds ratio divided by 1.65).

To test the robustness of our main impact results based on the fixed-effects models described above, we also performed ITT analyses using a two-level random-effects model as sensitivity analyses for the three primary outcomes in each of the two outcome domains (college enrollment and degree attainment). The specification of the random-effects model is similar to that of the fixed-effects model. The only difference between the two models is that the outcome difference between EC students and control students in each lottery (i.e., β_{1j} in Equation [1]) is modeled as a random effect with a random error (u_{1j}) at the lottery level in the random-effects model—as shown in Equation (6) below—rather than fixed to its grand mean as in the fixed-effects model:

$$\beta_{1j} = \gamma_{10} + u_{1j} \tag{6}$$

The level-2 coefficient γ_{10} from the above equation captures the overall treatment effect across all lotteries in the study, under the assumption that the lotteries in the study represent a larger population of EC admission lotteries.

For the categorical outcome of postsecondary enrollment profile, we estimated multinomial logistic regression models where the outcome of postsecondary enrollment profile in a given year has four possible values/categories: (1) had not enrolled in college (i.e., the baseline or reference category), (2) ever enrolled exclusively in 2-year colleges, (3) ever enrolled in a 4-year college with prior enrollment in a 2-year college, or (4) ever enrolled in a 4-year college without a prior enrollment in a 2-year college. The multinomial logistic regression model, which is a student-level regression with a treatment indicator, lottery (and sublottery) fixed effects, and controls for student background characteristics,[18] is specified as follows:

$$\log\left(\frac{p_{ij}}{p_{i1}}\right) = \sum_{k=1}^{K} \beta_{0k} LOT_{ki} + \beta_1 EC_i + \beta_2 \boldsymbol{X}_i,\ j = 2, 3, 4 \tag{7}$$

[18] These analyses were based on a single-level multinomial logistic regression model rather than a two-level model due to limitations in available software programs. As mentioned earlier, our main impact analyses were based on a two-level fixed-effects model rather than on a student-level model with lottery fixed effects in order to avoid the separation issue. For outcome measures without the separation issue, estimates based on the two alternative fixed-effects models were virtually identical.

where

- $\log\left(\frac{p_{ij}}{p_{i1}}\right)$ is the log odds of being in category *j* versus the baseline category (i.e., having not enrolled in college by the given year) for student *i*;
- LOT_{ki} is set of dummy indicators for the *k* lotteries (and sublotteries) in the study sample;
- EC_i is a dummy indicator for treatment status for student *i*, and
- $\boldsymbol{X}_i$ represents a vector of background characteristics for student *i*.

The primary coefficient of interest from the above model is β_1, which is the pooled within-lottery difference between EC and control students in the log odds of being in category *j* versus not having enrolled in college by the end of a given year. One sublottery (containing six students) was removed from this set of analyses because, within 2 years after expected high school graduation (i.e., by Year 6), all students in this sublottery had enrolled in college, and therefore relative risk ratios could not be estimated for students in this sublottery.

CATE Analyses

To take noncompliance into account, we supplemented the ITT analyses with CATE analyses for the three primary outcomes in each of the two outcome domains (i.e., college enrollment and degree attainment). While the ITT estimates capture the effects of being offered admission to an EC through a lottery, the CATE estimates capture the effects of actually attending an EC for students who complied with their treatment assignment (i.e., compliers) in the presence of noncompliance (i.e., no-shows and crossovers).

Across the 23 lotteries (including sublotteries) included in this study, no-shows (i.e., treatment students who did not attend the EC to which they were admitted through a lottery during the first year of high school) were fairly widespread and occurred in 18 lotteries, with an overall no-show rate of 20.9% among treatment students (see Exhibit D-1). Crossovers (i.e., control students who attended an EC during the first year of high school), however, occurred in only three lotteries, with an overall crossover rate of 2.0% among control students. The EC with the highest no-show rate (about 50% for all three cohorts) was in a district that ran districtwide lotteries for all schools where each student could participate in multiple school-specific lotteries. Some of the winners of the EC lottery in this district might have also won the lottery of another school that they preferred to attend. The lottery with the highest crossover rate (28.4%) was held by an EC located near another EC that was not part of the study. We classified control students who attended the non-study EC as crossovers because their high school experiences were similar to those of the treatment students.

Exhibit D-1. No-Show and Crossover Rates, by Study School and Cohort

School/Lottery	Ninth-Grade Student Cohort					
	Cohort 1 (2005–06)		Cohort 2 (2006–07)		Cohort 3 (2007–08)	
	No-Shows	Crossovers	No-Shows	Crossovers	No-Shows	Crossovers
School A			7.4%	0.0%		
School B			6.0%	28.4%	6.9%	2.3%
School C	45.5%	0.0%	58.1%	0.0%	57.4%	0.0%
School D						
• Lottery 1			36.7%	11.1%	12.2%	0.0%
• Lottery 2			28.6%	0.0%	0.0%	0.0%
School E	19.7%	0.0%				
• Lottery 1					12.5%	0.0%
• Lottery 2					0.0%	0.0%
• Lottery 3					16.7%	0.0%
School F			0.0%	0.0%	0.0%	0.0%
School H			3.8%	0.0%		
School I	16.2%	0.0%	39.4%	0.0%		
School J						
• Lottery 1					0.0%	0.0%
• Lottery 2					25.0%	0.0%
• Lottery 3					10.0%	0.0%

Note. No-show and crossover are defined based on whether a student attended an EC during the first year of high school. Rates were computed based on 2,032 students with the enrollment data needed. School G is not included in this exhibit because we were not able to obtain administrative data for this site. Shaded cells represent years that the school (1) was not yet open, (2) did not have a lottery, (3) did not have lottery records, or (4) did not have a graduating student cohort during the study period. Schools D, E, and J each had multiple lotteries for at least one student cohort.

We conducted the CATE analyses using the instrumental variable approach, which is particularly well suited for complier effect analysis in an experimental context (Angrist, Imbens, & Rubin, 1996; Gennetian, Morris, Bos, & Bloom, 2005; Schochet & Chiang, 2009). For our study, the lottery-based random assignment was a natural choice of instrument for EC attendance because it is expected to have a positive effect on EC attendance (as lottery winners were more likely to attend ECs), and EC attendance is likely to be the only plausible path through which winning an EC admission lottery could affect student outcomes. Moreover, it is unlikely that any EC applicant would deliberately do the opposite of the assignment received, regardless of the assignment. Thus, all three key assumptions under which the instrumental variable approach produces an unbiased CATE estimate (i.e., nonzero causal effect of treatment assignment on treatment receipt, exclusion restriction, and monotonicity [no defiers]) are likely to hold in this study.

Specifically, our instrumental variable analyses involved two stages. In the first stage, we obtained the predicted probability of attending an EC for each student based on a two-level model similar to the ITT impact model, with the dependent variable being a binary measure of EC attendance during the first year of high school. In the second stage, the predicted probability of EC attendance obtained from the first stage was used to predict the student outcome. The second-stage equation also was similar to the ITT impact model, except that the treatment indicator was replaced with the predicted probability of EC attendance. The second-stage coefficient for the predicted probability of EC attendance captures the EC effect on compliers. The CATE analysis does not take into account uncertainty in the stage 1 model when estimating the CATE in the stage 2 model, so standard errors may be somewhat underestimated. [19]

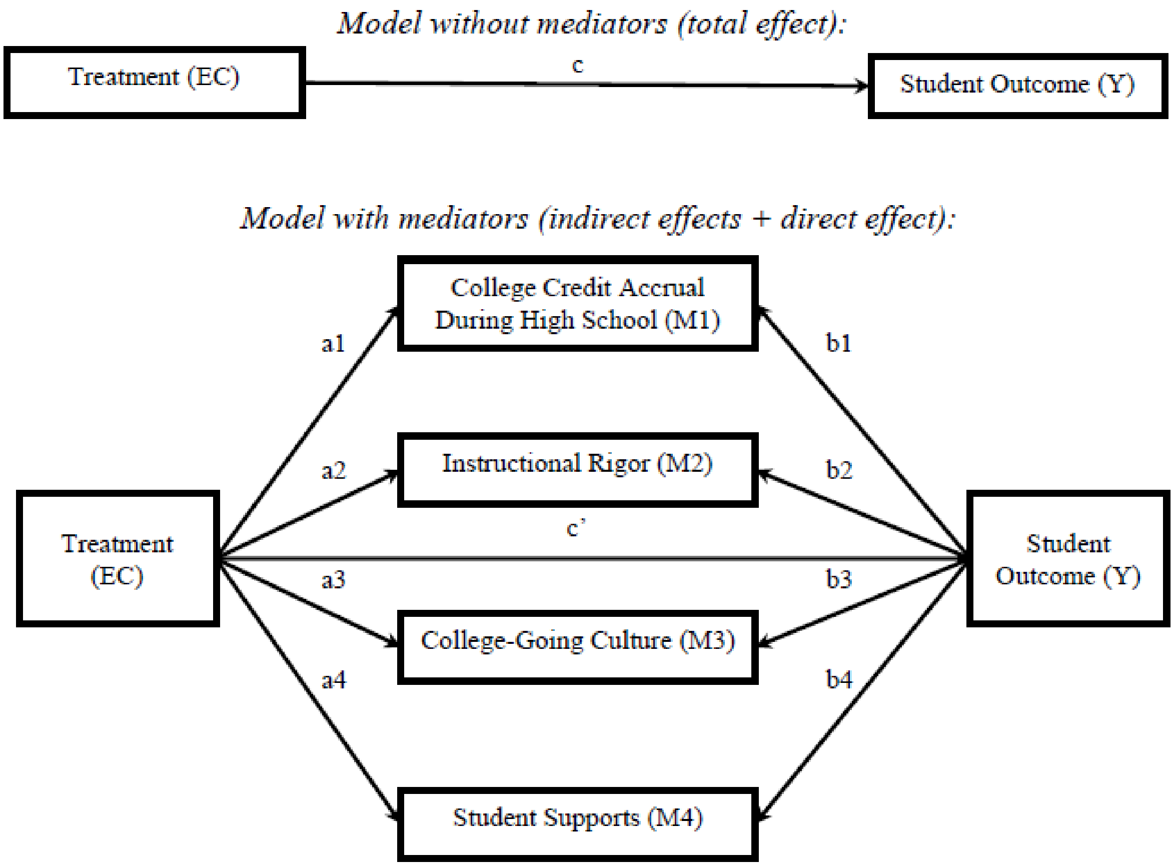
Mediation Analyses

Analyses that address RQ3 explored the mechanisms through which ECs affected student outcomes. Specifically, we examined the extent to which the EC impacts on postsecondary outcomes 6 years after expected high school graduation were mediated by students' high school experiences as captured by survey-based measures of *college credit accrual during high school, instructional rigor, college-going culture,* and *student support*.

The mediation analyses for degree attainment outcomes included all four measures of high school experiences as potential mediators, as illustrated in Exhibit D-2. Given that college credit accrual during high school implies college enrollment, we did not include college credit accrual during high school as a potential mediator in the mediation analyses for college enrollment outcomes. Other than the exclusion of this mediator, the model illustrated in Exhibit D-2 also applies to mediation analyses for college enrollment outcomes.

[19] We also estimated an alternative model using the *ivreg2* command in Stata. By simultaneously performing the stage 1 and stage 2 analyses, the *ivreg2* command overcomes the limitation of incorrectly estimating standard errors. However, *ivreg2* uses a single-level linear probability model to estimate both the probability of attending an EC (stage 1) and the impact on student outcomes (stage 2). The single-level model included lottery fixed effects to account for the clustering of students in lotteries. Results of these alternative analyses resemble the results of the CATE analyses presented in this report with one exception: the EC impact on bachelor's degree completion within 6 years after expected high school graduation (i.e., by Year 10) was only marginally significant (p = .060) using the *ivreg2* command.

Exhibit D-2. EC Impacts on Degree Completion Outcomes With and Without Mediators



The various paths representing the total effect (c), indirect effects (a_1*b_1, a_2*b_2, a_3*b_3, and a_4*b_4), and direct effect (c') in the mediation model were estimated with the models described below, all of which control for lottery fixed effects (LOT_{ki}) and student background characteristics ($\boldsymbol{X}_i$).[20]

Model for Estimating the Total Effect of ECs on a Binary Student Outcome:

$$\log\left(\frac{p_i}{1-p_i}\right) = \sum_{k=1}^{14} \beta_{0k} LOT_{ki} + cEC_i + \beta_2 \boldsymbol{X}_i \qquad (8)$$

[20] While our main impact analyses were based on a two-level model, our mediation analyses were based on a single-level model because the Stata program that we used for these analyses (*binary_mediation*) cannot accommodate multilevel models. As is the case with our two-level ITT impact model, our single-level mediation model also takes into account the clustering of students within lotteries and is also based on a fixed-effects rather than a random-effects approach.

The above model estimates the total effect of ECs on a binary student outcome, which is captured by coefficient c.

Model for Estimating EC Effects on Mediators[21]

$$\log\left(\frac{p_{M1i}}{1-p_{M1i}}\right) = \sum_{k=1}^{14} \beta_{0k} LOT_{ki} + a_1 EC_i + \beta_2 \boldsymbol{X}_i \quad (9)$$

$$M2_i = \sum_{k=1}^{14} \beta_{0k} LOT_{ki} + a_2 EC_i + \beta_2 \boldsymbol{X}_i + r_i \quad (10)$$

$$M3_i = \sum_{k=1}^{14} \beta_{0k} LOT_{ki} + a_3 EC_i + \beta_2 \boldsymbol{X}_i + r_i \quad (11)$$

$$M4_i = \sum_{k=1}^{14} \beta_{0k} LOT_{ki} + a_4 EC_i + \beta_2 \boldsymbol{X}_i + r_i \quad (12)$$

Equations 9 through 12 estimate the EC effects on the four mediators, respectively, using a model similar to the main impact model. The EC effect on the binary mediator (*M1*) was estimated using a logistic regression, and the EC effects on the three continuous mediators (*M2*, *M3*, and *M4*) were estimated using ordinary least squares regressions. This set of effects is captured by the coefficients $a1$, $a2$, $a3$, and $a4$, respectively.

Model for Estimating the Direct Effect of ECs and Mediator Effects on a Binary Student Outcome

$$\log\left(\frac{p'_i}{1-p'_i}\right) = \sum_{k=1}^{14} \beta_{0k} LOT_{ki} + c' EC_i + \sum_{m=1}^{4} b_m M_m + \beta_2 \boldsymbol{X}_i \quad (13)$$

In addition to the direct EC effect on the student outcome (i.e., c', the EC effect accounting for students' high school experiences), Equation 13 also estimates the effects of the four mediators on the student outcome, controlling for treatment status. This set of mediator effects is captured by coefficients $b1$, $b2$, $b3$, and $b4$, respectively.

To conduct the mediation analyses, we used the Stata program *binary_mediation* (Enders, 2011), which is capable of estimating indirect, direct, and total effects for models with a mixture of binary and continuous mediators and binary outcomes. Based on the estimates of the direct EC effect (*c'*) and the total EC effect (*c*), we calculated the percentage of the total EC effect that is explained by the high school experience measures. In addition, we calculated the percentage of the total EC effect that is explained by each of the mediators based on the indirect effect (i.e., *a**b*) associated with each mediator. Because our mediation model includes a binary mediator (*M1*) and three continuous mediators (*M2*, *M3*, and *M4*), the different path coefficients (i.e., *a*'s and *b*'s) and the total and direct effects (*c* and *c*') are not on a common

[21] To keep this set of equations simple, subscripts are not used to distinguish the coefficients in the different equations. Thus, the coefficients shown with the same notation in different equations (e.g., β_{0k} and β_2) represent different parameter estimates in equations associated with different mediators.

scale. Therefore, to examine the magnitude of indirect effects relative to the total or direct effect of ECs, the different path coefficients as well as the total EC effect and direct EC effect were rescaled using the standardization method developed by MacKinnon and Dwyer (1993).

Following the recommendation by Preacher and Hayes (2008), we tested the significance of the indirect effect associated with each mediator and the total indirect effect across all four mediators using bias-corrected, bootstrap confidence intervals based on 5,000 resamples. Compared with alternative approaches to testing the significance of indirect effects (e.g., the product-of-coefficient approach), bootstrapping, as a nonparametric resampling procedure, does not impose the assumption of normality of the sampling distribution and is considered the most powerful and reasonable method of obtaining confidence intervals for indirect effects under most conditions (Briggs, 2006; Preacher & Hayes, 2008; Williams, 2004; Williams & MacKinnon, 2008).

Appendix E. Missing Data

In this appendix, we present the percentage of EC and control students with missing data on student background characteristics and high school experience measures. For impact and mediation analyses, we performed multiple imputation to account for missing data, and we conducted analyses on the resulting 10 imputed data sets.

Exhibit E-1. Percentage of Students With Missing Data on Background Characteristics Prior to Imputation, Overall and by Study Group

Student Characteristic	Overall (*n* = 2,458)	EC Group (*n* = 1,044)	Control Group (*n* = 1,414)
Female	8.1%	12.0%	5.3%
Nonwhite	8.4%	12.4%	5.5%
First-generation college-going	49.1%	33.3%	60.8%
Low income	16.2%	22.7%	11.3%
Prior achievement in English language arts	23.8%	25.9%	22.3%
Prior achievement in mathematics	23.9%	26.0%	22.3%

Exhibit E-2. Percentage of Students With Missing Data on High School Experience Measures Prior to Imputation, Overall and by Study Group

High School Experience Measures	Overall (*n* = 1,424)	EC Group (*n* = 771)	Control Group (*n* = 653)
College credit accrual during high school	11.7%	9.1%	14.7%
College-going culture	9.8%	7.1%	12.9%
Academic rigor	9.8%	7.3%	12.9%
Student support	9.8%	7.1%	12.9%

Appendix F. Summary of Study Findings

In this appendix, we provide detailed findings from the impact, CATE, differential impact, and mediation analyses performed for the efficacy follow-up study of EC high schools.

Impact Estimates

Exhibit F-1. ITT Estimates of the Overall EC Impacts on College Enrollment Outcomes

Outcome	Effect in Logits	Standard Error	EC Group Probability	Control Group Probability	Difference	Effect Size	*p*-Value
College enrollment by Year 10	0.464	0.121	84.2%	77.0%	7.2%	0.281	.000
2-year college enrollment by Year 10	0.781	0.108	65.8%	46.8%	19.0%	0.474	.000
4-year college enrollment by Year 10	0.035	0.106	57.6%	56.7%	0.8%	0.021	.744
Selective 4-year college enrollment by Year 10	0.008	0.160	17.8%	17.7%	0.1%	0.005	.959
College enrollment by Year 4	1.775	0.115	63.8%	23.0%	40.8%	1.076	.000
College enrollment by Year 5	0.509	0.112	78.9%	69.2%	9.7%	0.308	.000
College enrollment by Year 6	0.520	0.116	81.8%	72.8%	9.0%	0.315	.000
College enrollment by Year 7	0.465	0.118	82.6%	74.9%	7.7%	0.282	.000
College enrollment by Year 8	0.478	0.120	83.3%	75.6%	7.7%	0.290	.000
College enrollment by Year 9	0.481	0.121	83.8%	76.2%	7.6%	0.292	.000
2-year college enrollment by Year 4	1.775	0.115	48.9%	11.3%	37.6%	1.222	.000
2-year college enrollment by Year 5	0.509	0.112	57.0%	31.9%	25.1%	0.630	.000
2-year college enrollment by Year 6	0.520	0.116	61.3%	39.1%	22.2%	0.548	.000
2-year college enrollment by Year 7	0.465	0.118	62.9%	43.2%	19.7%	0.487	.000
2-year college enrollment by Year 8	0.478	0.120	64.2%	45.0%	19.2%	0.475	.000
2-year college enrollment by Year 9	0.481	0.121	64.9%	46.0%	19.0%	0.472	.000

Outcome	Effect in Logits	Standard Error	EC Group Probability	Control Group Probability	Difference	Effect Size	*p*-Value
4-year college enrollment by Year 4	1.060	0.172	22.3%	9.1%	13.3%	0.642	.000
4-year college enrollment by Year 5	0.167	0.109	49.2%	45.1%	4.1%	0.101	.128
4-year college enrollment by Year 6	0.237	0.107	53.4%	47.5%	5.9%	0.144	.026
4-year college enrollment by Year 7	0.137	0.106	55.2%	51.8%	3.4%	0.083	.196
4-year college enrollment by Year 8	0.109	0.106	55.9%	53.2%	2.7%	0.066	.300
4-year college enrollment by Year 9	0.079	0.106	56.9%	54.9%	1.9%	0.048	.455
Selective 4-year college enrollment by Year 4	2.043	0.467	6.1%	0.8%	5.3%	1.238	.000
Selective 4-year college enrollment by Year 5	0.107	0.199	12.6%	11.4%	1.1%	0.065	.592
Selective 4-year college enrollment by Year 6	0.162	0.193	13.6%	11.8%	1.8%	0.098	.400
Selective 4-year college enrollment by Year 7	0.049	0.180	14.6%	14.0%	0.6%	0.030	.783
Selective 4-year college enrollment by Year 8	0.042	0.167	16.6%	16.0%	0.6%	0.026	.800
Selective 4-year college enrollment by Year 9	0.027	0.162	17.3%	17.0%	0.4%	0.017	.866

Notes. *N* = 2,458 (1,044 EC, 1,414 control). The EC group percentages are unadjusted percentages; the control group percentages were computed based on the unadjusted EC group percentages and estimated EC effects. We computed the effect sizes for these binary outcomes by dividing the logged odds ratio by 1.65 (i.e., the Cox index), as recommended by the WWC.
Year x, x = 4~10, refers to x years after starting high school.

Exhibit F-2. ITT Estimates of the Overall EC Impacts on Enrollment Profiles

Outcome	Effect in Logits	Standard Error	Treatment Group Relative Risk	Control Group Relative Risk	Relative Risk Ratio	*p*-Value
Enrollment Exclusively in 2-Year Colleges (relative to not enrolled in college)						
Year 5	0.719	0.131	1.414	0.688	2.053	.000
Year 6	0.671	0.136	1.568	0.802	1.956	.000
Year 7	0.637	0.139	1.571	0.831	1.892	.000
Year 8	0.671	0.140	1.644	0.841	1.955	.000
Year 9	0.702	0.142	1.663	0.824	2.018	.000
Year 10	0.715	0.143	1.685	0.824	2.045	.000
Enrollment in a 4-Year College With a Prior Enrollment in a 2-Year College (relative to not enrolled in college)						
Year 5	1.816	0.183	1.177	0.192	6.148	.000
Year 6	1.688	0.171	1.547	0.286	5.407	.000
Year 7	1.378	0.161	1.703	0.430	3.965	.000
Year 8	1.306	0.159	1.816	0.492	3.692	.000
Year 9	1.230	0.157	1.923	0.562	3.420	.000
Year 10	1.168	0.156	2.006	0.624	3.215	.000
Enrollment in a 4-Year College Without a Prior Enrollment in a 2-Year College (relative to not enrolled in college)						
Year 5	-0.337	0.156	1.155	1.618	0.714	.030
Year 6	-0.271	0.157	1.379	1.808	0.763	.084
Year 7	-0.356	0.159	1.462	2.086	0.700	.026
Year 8	-0.356	0.160	1.540	2.198	0.701	.027
Year 9	-0.383	0.162	1.592	2.335	0.682	.018
Year 10	-0.414	0.163	1.636	2.477	0.661	.011

Notes. N = 2,452 (1,041 treatment, 1,411 control). Relative risks for EC students were computed based on the unadjusted percentage of EC students in each of the enrollment categories in a given year. Relative risks for control students are adjusted relative risks that were computed based on the unadjusted relative risks for EC students and estimated EC effects. The relative risk ratio for each enrollment profile outcome is the ratio of the EC relative risk to the control group relative risk.
Year x, x = 5~10, refers to x years after starting high school.

Exhibit F-3. ITT Estimates of the Overall EC Impacts on Degree Attainment Outcomes

Outcome	Effect in Logits	Standard Error	EC Group Probability	Control Group Probability	Difference	Effect Size	*p*-Value
Completed any degree by Year 10	0.503	0.111	45.4%	33.5%	11.9%	0.305	.000
Completed an associate's degree or certificate by Year 10	1.197	0.132	29.3%	11.1%	18.2%	0.725	.000
Completed a bachelor's degree by Year 10	0.259	0.124	30.1%	24.9%	5.2%	0.157	.037
Completed any degree by Year 4	3.492	0.314	21.7%	0.8%	20.9%	2.116	.000
Completed any degree by Year 5	3.123	0.259	23.7%	1.3%	22.3%	1.893	.000
Completed any degree by Year 6	2.550	0.207	25.0%	2.5%	22.5%	1.546	.000
Completed any degree by Year 7	1.944	0.164	27.7%	5.2%	22.5%	1.178	.000
Completed any degree by Year 8	1.017	0.121	37.7%	18.0%	19.8%	0.616	.000
Completed any degree by Year 9	0.593	0.112	43.3%	29.7%	13.6%	0.360	.000
Completed an associate's degree or certificate by Year 4	3.492	0.314	21.7%	0.8%	20.9%	2.116	.000
Completed an associate's degree or certificate by Year 5	3.123	0.259	23.7%	1.3%	22.3%	1.893	.000
Completed an associate's degree or certificate by Year 6	2.524	0.207	24.5%	2.5%	22.0%	1.530	.000
Completed an associate's degree or certificate by Year 7	2.018	0.171	25.9%	4.4%	21.4%	1.223	.000
Completed an associate's degree or certificate by Year 8	1.605	0.150	27.1%	7.0%	20.2%	0.973	.000

Outcome	Effect in Logits	Standard Error	EC Group Probability	Control Group Probability	Difference	Effect Size	*p*-Value
Completed an associate's degree or certificate by Year 9	1.382	0.139	28.6%	9.2%	19.5%	0.837	.000
Completed a bachelor's degree by Year 6	4.304	1.699	2.3%	0.0%	2.3%	2.608	.011
Completed a bachelor's degree by Year 7	2.351	0.361	7.8%	0.8%	7.0%	1.425	.000
Completed a bachelor's degree by Year 8	0.760	0.152	20.7%	10.9%	9.8%	0.461	.000
Completed a bachelor's degree by Year 9	0.288	0.127	27.5%	22.1%	5.4%	0.175	.023

Notes. *N* = 2,458 (1,044 EC, 1,414 control). The EC group probabilities are unadjusted probabilities; the control group probabilities were computed based on the unadjusted EC group probabilities and estimated EC effects. We computed the effect sizes for these binary outcomes by dividing the logged odds ratio by 1.65 (i.e., the Cox index), as recommended by the WWC.
Year x, x = 4~10, refers to x years after starting high school.

Exhibit F-4. ITT and CATE Estimates of the Overall EC Impacts on Primary Study Outcomes

Outcome	Analysis Type	Effect in Logits	Standard Error	EC Group Probability	Control Group Probability	Difference	Effect Size	*p*-Value
College Enrollment by Year 10								
Any college	ITT	0.464	0.121	84.2%	77.0%	7.2%	0.281	.000
	CATE	0.817	0.174	86.1%	73.2%	12.9%	0.495	.000
2-year college	ITT	0.781	0.108	65.8%	46.8%	19.0%	0.474	.000
	CATE	1.205	0.152	69.2%	40.2%	29.0%	0.730	.000
4-year college	ITT	0.035	0.106	57.6%	56.7%	0.8%	0.021	.744
	CATE	0.135	0.144	60.1%	56.8%	3.3%	0.082	.348
Degree Completion by Year 10								
Any degree	ITT	0.503	0.111	45.4%	33.5%	11.9%	0.305	.000
	CATE	0.748	0.144	50.9%	32.9%	18.0%	0.453	.000
Associate's degree or certificate	ITT	1.197	0.132	29.3%	11.1%	18.2%	0.725	.000
	CATE	1.636	0.173	33.8%	9.0%	24.8%	0.991	.000
Bachelor's degree	ITT	0.259	0.124	30.1%	24.9%	5.2%	0.157	.037
	CATE	0.415	0.156	33.6%	25.1%	8.6%	0.251	.008

Notes. *N* = 2,458 (1,044 EC, 1,414 control). The EC group probabilities are unadjusted probabilities based on all EC students for the intent-to-treat (ITT) findings and based on compliers (i.e., EC students who enrolled in an EC in the fall of the first year of high school) for the complier average treatment effect (CATE) findings. The control group probabilities were computed based on the unadjusted EC group probabilities and estimated EC effects.
We computed the effect sizes for these binary outcomes by dividing the logged odds ratio by 1.65 (i.e., the Cox index), as recommended by the WWC.

Estimates of Differential Impact

Exhibit F-5. Differential EC Impacts on College Enrollment and Degree Attainment Outcomes by the End of Year 10, by Prior Achievement

Outcome by the End of Year 10	Prior Ach.=1 SD Below Average			Prior Ach.=Average			Prior Ach.=1 SD Above Average			Differential Impact	
	EC Group Probability	Control Group Probability	Diff.	EC Group Probability	Control Group Probability	Diff.	EC Group Probability	Control Group Probability	Diff.	Odds Ratio	*p*-Value
Differential Impact by Prior ELA Achievement											
College enrollment	81.9%	75.2%	6.7%	87.4%	81.0%	6.3%	91.3%	85.8%	5.6%	1.1	.601
2-year college enrollment	69.8%	59.2%	10.6%	80.2%	64.8%	15.5%	87.7%	70.0%	17.8%	1.4	.011
4-year college enrollment	38.1%	38.8%	-0.7%	50.3%	49.6%	0.8%	62.6%	60.3%	2.2%	1.1	.623
Completed any degree	31.6%	24.7%	6.9%	42.2%	31.4%	10.8%	53.6%	38.9%	14.6%	1.1	.398
Completed an associate's degree or certificate	22.7%	14.6%	8.1%	36.2%	16.4%	19.8%	52.4%	18.5%	33.9%	1.7	.004
Completed a bachelor's degree	13.2%	11.7%	1.5%	20.2%	16.8%	3.4%	29.6%	23.7%	6.0%	1.1	.611
Differential Impact by Prior Mathematics Achievement											
College enrollment	82.8%	74.4%	8.4%	87.0%	81.0%	6.1%	90.4%	86.2%	4.2%	1.0	.744
2-year college enrollment	75.0%	62.4%	12.7%	80.1%	64.8%	15.3%	84.3%	67.2%	17.2%	1.2	.099
4-year college enrollment	37.1%	38.4%	-1.3%	50.3%	49.6%	0.7%	63.4%	60.8%	2.6%	1.1	.500
Completed any degree	27.4%	22.2%	5.3%	41.8%	31.4%	10.3%	57.7%	42.5%	15.2%	1.2	.272
Completed an associate's degree or certificate	21.0%	15.7%	5.3%	35.1%	16.5%	18.5%	52.3%	17.4%	34.9%	1.9	.000
Completed a bachelor's degree	14.0%	10.4%	3.6%	21.2%	16.8%	4.4%	30.9%	26.1%	4.8%	0.9	.742

Notes. Ach. = achievement; Diff. = difference; ELA = English language arts; SD = standard deviation. *N* = 2,458 (1,044 EC, 1,414 control). The EC and control group probabilities for a given level of prior achievement (i.e., 1 SD below the state average, state average, and 1 SD above the state average) are predicted probabilities when all control variables other than the prior achievement measure were set to their grand means. The values in the Diff. columns may not match the difference between the EC and control group probabilities due to rounding.

Exhibit F-6. Differential EC Impacts on College Enrollment and Degree Attainment Outcomes by the End of Year 10, by Student Background Characteristics

Outcome by the End of Year 10	X = 1				X = 0				Differential Impact		
	EC Group Probability	Control Group Probability	Diff.	*N*	EC Group Probability	Control Group Probability	Diff.	*N*	Odds Ratio	Difference in Impact	*p*-Value
Differential Impact by Gender (X = 1 for female)											
College enrollment	85.8%	80.1%	5.7%	1,260	82.5%	73.7%	8.8%	1,198	0.9	-3.1%	.656
2-year college enrollment	69.9%	52.1%	17.8%	1,260	61.5%	41.7%	19.8%	1,198	1.0	-2.0%	.836
4-year college enrollment	58.6%	58.9%	-0.3%	1,260	56.4%	54.3%	2.1%	1,198	0.9	-2.4%	.656
Completed any degree	49.4%	38.4%	11.0%	1,260	41.2%	28.3%	12.8%	1,198	0.9	-1.8%	.599
Completed an associate's degree or certificate	32.3%	12.2%	20.1%	1,260	26.1%	10.1%	16.1%	1,198	1.1	4.0%	.774
Completed a bachelor's degree	33.9%	28.5%	5.4%	1,260	26.1%	21.2%	4.8%	1,198	1.0	0.6%	.949
Differential Impact by Race/Ethnicity (X = 1 for non-White)											
College enrollment	84.5%	79.2%	5.3%	954	87.2%	78.5%	8.6%	866	0.8	-3.3%	.372
2-year college enrollment	72.9%	54.5%	18.4%	954	62.6%	36.8%	25.8%	866	0.8	-7.4%	.316
4-year college enrollment	59.8%	56.9%	2.9%	954	59.6%	61.3%	-1.7%	866	1.2	4.7%	.436
Completed any degree	44.7%	30.9%	13.8%	954	53.3%	40.7%	12.6%	866	1.1	1.2%	.729
Completed an associate's degree or certificate	31.2%	9.4%	21.8%	954	33.1%	13.0%	20.0%	866	1.3	1.7%	.327
Completed a bachelor's degree	32.1%	24.8%	7.3%	954	33.0%	29.4%	3.6%	866	1.2	3.7%	.463

Outcome by the End of Year 10	X = 1				X = 0				Differential Impact		
	EC Group Probability	Control Group Probability	Diff.	*N*	EC Group Probability	Control Group Probability	Diff.	*N*	Odds Ratio	Difference in Impact	*p*-Value
Differential Impact by Low-Income Status (X = 1 for students eligible for free or reduced-price lunch)											
College enrollment	81.4%	72.2%	9.2%	1,313	87.8%	81.0%	6.7%	1,075	1.0	2.5%	.983
2-year college enrollment	65.0%	44.4%	20.5%	1,313	66.4%	47.6%	18.8%	1,075	1.1	1.7%	.794
4-year college enrollment	53.2%	51.4%	1.8%	1,313	62.7%	61.9%	0.8%	1,075	1.0	1.0%	.865
Completed any degree	38.8%	25.6%	13.2%	1,313	52.8%	40.6%	12.2%	1,075	1.1	1.0%	.620
Completed an associate's degree or certificate	27.2%	8.9%	18.3%	1,313	31.5%	12.7%	18.8%	1,075	1.2	-0.6%	.520
Completed a bachelor's degree	24.3%	19.2%	5.1%	1,313	36.4%	30.7%	5.7%	1,075	1.0	-0.6%	.872

Notes: Diff. = difference. The EC group probabilities within a given student subgroup are unadjusted probabilities; the control group probabilities were computed based on the unadjusted EC group probabilities and estimated EC effects within the subgroup.

The values in the Diff. columns may not match the difference between the EC and control group probabilities due to rounding. Two lotteries were excluded from the analyses of differential impact by minority status because zero EC students were nonminority, and thus EC impacts among nonminority students could not be estimated within these lotteries. Similarly, one lottery was removed from the analyses of differential impact by low-income status because zero students within this lottery were from low-income families.

Findings from Mediation Analyses

Exhibit F-7. Estimates of EC Impacts on High School Experiences Based on the Survey Sample

Outcome	Effect	Standard Error	EC Group Mean	Control Group Mean	Difference	Effect Size	*p*-Value
College credit accrual during high school[a]	1.412	0.186	69.3%	35.5%	33.8%	0.856	.000
College-going culture	0.357	0.074	0.143	-0.214	0.357	0.357	.000
Student support	0.362	0.072	0.136	-0.225	0.362	0.362	.000
Instructional rigor	0.373	0.070	0.159	-0.213	0.373	0.373	.000

Note. *N* = 1,424 (771 treatment, 653 control). The EC group means are unadjusted means; the control group means were computed based on the unadjusted EC group means and estimated EC effects.
[a] The EC effect on the binary measure of college credit accrual during high school is on the logit scale; effects on the three continuous measures are on a standardized scale with a mean of 0 and a standard deviation of 1.

Exhibit F-8. Total EC Effects on Primary College Enrollment and Degree Attainment Outcomes Based on the Survey Sample

Outcome	Effect in Logits	Standard Error	EC Group Probability	Control Group Probability	Difference	Effect Size	*p*-Value
College Enrollment Within 6 Years after Expected High School Graduation							
Any college	0.593	0.118	82.7%	72.5%	10.2%	0.359	.000
2-year college	0.894	0.104	62.1%	40.2%	22.0%	0.542	.000
4-year college	0.006	0.102	61.1%	60.9%	0.1%	0.004	.952
Degree Completion Within 6 Years after Expected High School Graduation							
Any degree	0.625	0.107	45.5%	30.9%	14.6%	0.379	.000
Associate's degree or certificate	1.344	0.128	27.2%	8.9%	18.3%	0.815	.000
Bachelor's degree	0.315	0.120	32.0%	25.6%	6.4%	0.191	.009

Notes. *N* = 1,424 (771 EC, 653 control). The EC group probabilities are unadjusted probabilities; the control group probabilities were computed based on the unadjusted EC group probabilities and estimated EC effects.

Exhibit F-9. Distribution of Direct and Indirect Effects of ECs on Primary College Enrollment and Degree Attainment Outcomes Based on the Survey Sample

Outcome	Percentage of Total Effect That Is a Direct Effect	Indirect Effects: Percentage of Total Effect Explained by				Percentage of Total Effect That Is an Indirect Effect
		College Credit Accrual During High School	Instructional Rigor	College-Going Culture	Student Supports	
College Enrollment Within 6 Years after Expected High School Graduation						
Any college	71.5%	N/A	7.5%	10.3%	10.7%	28.5%**
2-year college	96.6%***	N/A	-1.8%	-1.2%	6.4%	3.4%
Degree Completion Within 6 Years after Expected High School Graduation						
Any degree	40.9%	50.3%***	-7.9%	12.0%*	4.7%	59.1%***
Associate's degree or certificate	78.9%***	9.8%	0.1%	7.1%*	4.1%	21.1%**
Bachelor's degree	14.5%	87.3%***	-17.0%	9.9%	5.4%	85.5%***

Notes. N = 1,424 (771 EC, 653 control).
N/A = not applicable; college credit accrual during high school was not included as a mediator for college enrollment outcomes.
We did not explore direct or indirect effects for the outcome of enrollment in a 4-year college within 6 years after expected high school graduation because the total effect on this outcome was not statistically significant.
* $p < .05$; ** $p < .01$; *** $p < .001$.

Appendix G. Sensitivity Analyses

Comparing Impact Results With and Without the Site With Imputed Administrative Data

For the original Impact Study of Early College High Schools, the research team collected administrative data from participating schools, districts, and states. Upon updating data agreements at the beginning of this follow-up study in 2016, we were informed that one state that provided administrative data no longer allowed researchers to access identifiable student-level data. Because student identifiers were necessary to link student background data both to survey data and to postsecondary data obtained from NSC, we could no longer use administrative data from this state in our analyses, and all student background information was imputed for students who participated in the lottery at the one site in this state.

To assess whether the imputed background information for the students at this site affected our overall study findings, we performed a set of sensitivity analyses that estimated EC impacts on college enrollment and degree completion outcomes without this site. The results of these analyses are presented in Exhibits G-1 and G-2, respectively. Overall, the results from this set of sensitivity analyses mirror the results based on the full study sample (see Appendix Exhibits F-1 and F-3) with one exception. While the impact on bachelor's degree completion within 6 years after expected high school graduation was statistically significant based on the full sample, it was no longer significant at the .05 level (but marginally significant at the .10 level) after excluding the one site in which all study participants had imputed background data. EC impacts on bachelor's degree completion in previous years remained statistically significant based on the reduced sample.

Exhibit G-1. ITT Estimates of the Overall EC Impacts on College Enrollment Outcomes, Excluding One Site With Completely Imputed Student Background Data

Outcome	Effect in Logits	Standard Error	EC Group Probability	Control Group Probability	Difference	Effect Size	*p*-Value
College enrollment by Year 10	0.519	0.128	84.1%	75.9%	8.2%	0.314	.000
2-year college enrollment by Year 10	0.824	0.110	73.4%	54.7%	18.6%	0.499	.000
4-year college enrollment by Year 10	0.044	0.110	54.0%	52.9%	1.1%	0.027	.688
College enrollment by Year 4	1.952	0.124	62.4%	19.1%	43.3%	1.183	.000
College enrollment by Year 5	0.563	0.118	78.9%	68.1%	10.9%	0.341	.000
College enrollment by Year 6	0.567	0.123	82.0%	72.0%	9.9%	0.344	.000

Outcome	Effect in Logits	Standard Error	EC Group Probability	Control Group Probability	Difference	Effect Size	*p*-Value
College enrollment by Year 7	0.512	0.125	82.5%	73.9%	8.6%	0.310	.000
College enrollment by Year 8	0.522	0.127	83.3%	74.7%	8.6%	0.316	.000
College enrollment by Year 9	0.528	0.128	83.7%	75.2%	8.5%	0.320	.000
2-year college enrollment by Year 4	2.039	0.131	55.2%	13.8%	41.4%	1.236	.000
2-year college enrollment by Year 5	1.068	0.108	64.2%	38.2%	26.1%	0.647	.000
2-year college enrollment by Year 6	0.922	0.108	68.7%	46.6%	22.1%	0.559	.000
2-year college enrollment by Year 7	0.829	0.109	70.5%	51.1%	19.4%	0.502	.000
2-year college enrollment by Year 8	0.817	0.109	72.0%	53.1%	18.8%	0.495	.000
2-year college enrollment by Year 9	0.819	0.110	72.7%	54.0%	18.7%	0.496	.000
4-year college enrollment by Year 4	1.273	0.204	15.3%	4.8%	10.5%	0.771	.000
4-year college enrollment by Year 5	0.180	0.115	45.2%	40.8%	4.4%	0.109	.117
4-year college enrollment by Year 6	0.254	0.112	50.0%	43.7%	6.3%	0.154	.023
4-year college enrollment by Year 7	0.149	0.111	51.5%	47.8%	3.7%	0.090	.179
4-year college enrollment by Year 8	0.114	0.110	52.3%	49.4%	2.9%	0.069	.298
4-year college enrollment by Year 9	0.084	0.110	53.3%	51.2%	2.1%	0.051	.444

Notes. N = 2,260 (920 EC, 1,340 control). The EC group probabilities are unadjusted probabilities; the control group probabilities were computed based on the unadjusted EC group probabilities and estimated EC effects. We computed the effect sizes for these binary outcomes by dividing the logged odds ratio by 1.65 (i.e., the Cox index), as recommended by the WWC.

Year x, x = 4~10, refers to x years after starting high school.

Exhibit G-2. ITT Estimates of the Overall EC Impact on Degree Attainment Outcomes, Excluding One Site With Completely Imputed Background Data

Outcome	Effect in Logits	Standard Error	EC Group Probability	Control Group Probability	Difference	Effect Size	*p*-Value
Completed any degree by Year 10	0.467	0.119	43.4%	32.4%	10.9%	0.283	0.000
Completed an associate's degree or certificate by Year 10	1.193	0.144	26.1%	9.7%	16.4%	0.723	0.000
Completed a bachelor's degree by Year 10	0.220	0.132	29.9%	25.5%	4.4%	0.133	0.096
Completed any degree by Year 4	4.399	0.460	19.8%	0.3%	19.5%	2.666	0.000
Completed any degree by Year 5	3.569	0.320	21.6%	0.8%	20.9%	2.163	0.000
Completed any degree by Year 6	2.843	0.244	22.6%	1.7%	20.9%	1.723	0.000
Completed any degree by Year 7	2.069	0.184	25.2%	4.1%	21.1%	1.254	0.000
Completed any degree by Year 8	1.008	0.130	36.0%	17.0%	19.0%	0.611	0.000
Completed any degree by Year 9	0.558	0.120	41.2%	28.6%	12.6%	0.338	0.000
Completed an associate's degree or certificate by Year 4	4.399	0.460	19.8%	0.3%	19.5%	2.666	0.000
Completed an associate's degree or certificate by Year 5	3.569	0.320	21.6%	0.8%	20.9%	2.163	0.000
Completed an associate's degree or certificate by Year 6	2.815	0.244	22.2%	1.7%	20.5%	1.706	0.000
Completed an associate's degree or certificate by Year 7	2.154	0.193	23.3%	3.4%	19.9%	1.305	0.000
Completed an associate's degree or certificate by Year 8	1.661	0.166	24.3%	5.8%	18.6%	1.006	0.000

Outcome	Effect in Logits	Standard Error	EC Group Probability	Control Group Probability	Difference	Effect Size	*p*-Value
Completed an associate's degree or certificate by Year 9	1.407	0.153	25.4%	7.7%	17.7%	0.853	0.000
Completed a bachelor's degree by Year 6	4.452	1.963	21.7%	0.3%	21.4%	2.698	0.023
Completed a bachelor's degree by Year 7	2.399	0.383	78.3%	24.6%	53.6%	1.454	0.000
Completed a bachelor's degree by Year 8	0.752	0.159	21.2%	11.3%	9.9%	0.456	0.000
Completed a bachelor's degree by Year 9	0.271	0.134	27.8%	22.7%	5.1%	0.164	0.044

Notes. *N* = 2,260 (920 EC, 1,340 control). The EC group probabilities are unadjusted probabilities; the control group probabilities were computed based on the unadjusted EC group probabilities and estimated EC effects. We computed the effect sizes for these binary outcomes by dividing the logged odds ratio by 1.65 (i.e., the Cox index), as recommended by the WWC.
Year x, x = 4~10, refers to x years after starting high school.

Comparing Results Based on Fixed-Effects and Random-Effects Models

Exhibit G-3 provides a comparison of results from fixed-effects models and random-effects models for the primary college enrollment and degree attainment outcomes. In general, results based on the random-effects model align with the results based on the fixed-effects model. However, while the EC impact on completion of a bachelor's degree within 6 years after expected high school graduation (i.e., by Year 10) was statistically significant based on the fixed-effects model, it was slightly smaller and no longer significant based on the random-effects model.

Exhibit G-3. ITT Estimates of the Overall EC Impacts on Primary College Enrollment and Degree Attainment Outcomes Based on Fixed-Effects and Random-Effects Models

Outcome	Model	Effect in Logit	Standard Error	EC Group Probability	Control Group Probability	Difference	Effect Size	p-Value
College Enrollment by Year 10								
Any college	Fixed-effects	0.464	0.121	84.2%	77.0%	7.2%	0.281	.000
	Random-effects	0.464	0.179	84.2%	77.0%	7.2%	0.281	.010
2-year college	Fixed-effects	0.781	0.108	65.8%	46.8%	19.0%	0.474	.000
	Random-effects	0.918	0.190	65.8%	43.5%	22.4%	0.556	.000
4-year college	Fixed-effects	0.035	0.106	57.6%	56.7%	0.8%	0.021	.744
	Random-effects	0.044	0.136	57.6%	56.5%	1.1%	0.026	.749
Degree Completion by Year 10								
Any degree	Fixed-effects	0.503	0.111	45.4%	33.5%	11.9%	0.305	.000
	Random-effects	0.449	0.225	45.4%	34.7%	10.7%	0.272	.046
Associate's degree or certificate	Fixed-effects	1.197	0.132	29.3%	11.1%	18.2%	0.725	.000
	Random-effects	0.968	0.306	29.3%	13.6%	15.7%	0.586	.002
Bachelor's degree	Fixed-effects	0.259	0.124	30.1%	24.9%	5.2%	0.157	.037
	Random-effects	0.205	0.145	30.2%	26.0%	4.1%	0.124	.159

Notes. N = 2,458 (1,044 EC, 1,414 control). The EC group probabilities are unadjusted probabilities; the control group probabilities were computed based on the unadjusted EC group probabilities and estimated EC effects. We computed the effect sizes for these binary outcomes by dividing the logged odds ratio by 1.65 (i.e., the Cox index), as recommended by the WWC.

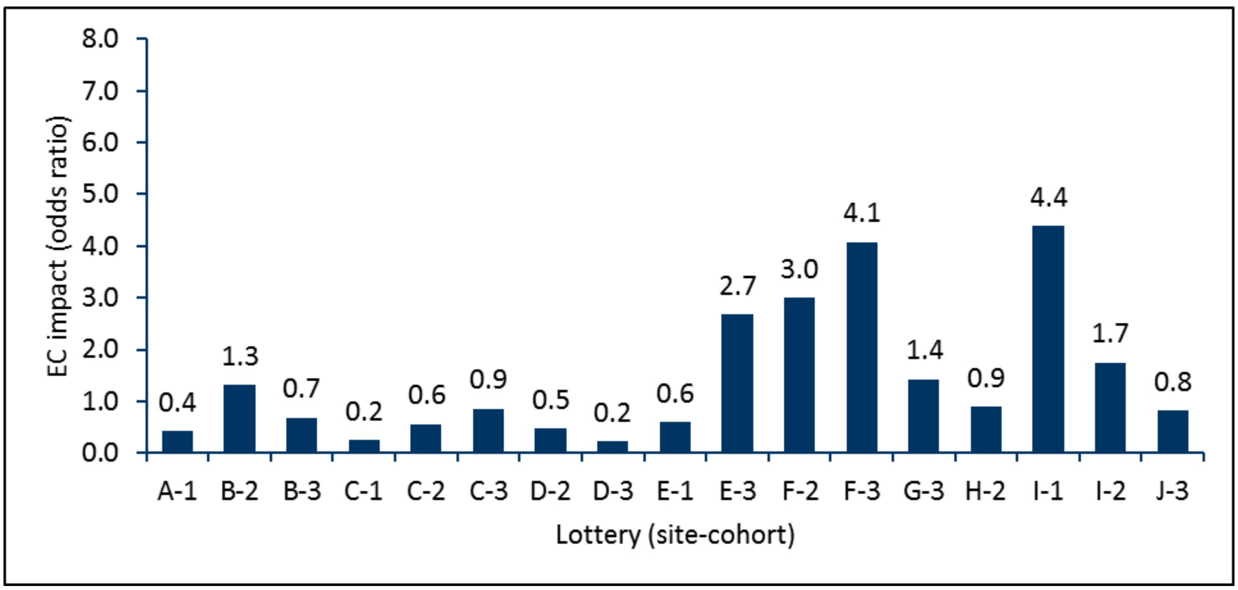
Exhibit G-4 presents the variance of EC impact on each primary study outcome based on the random-effects model. It reveals significant variation in EC impact across lotteries for the outcomes of completing any type of postsecondary degree and completing an associate's degree or certificate by Year 10 (see Exhibits G-5 and G-6 for a graphic depiction of the variation of EC impacts on these two outcomes). For the other primary study outcomes, we did not observe significant variation in EC impact across lotteries.

Exhibit G-4. Variance Estimates of the Random-Effects Impact Estimates for Primary College Enrollment and Degree Completion Outcomes

Outcome	Variance of EC Effect (logit squared)	Standard Error	T-Statistic	*p*-Value
College Enrollment by Year 10				
Any college	0.166	0.161	1.033	0.302
2-year college	0.353	0.200	1.768	0.077
4-year college	0.104	0.109	0.962	0.336
Degree Completion by Year 10				
Any degree	0.596	0.302	1.977	0.048
Associate's degree or certificate	1.177	0.558	2.107	0.035
Bachelor's degree	0.052	0.094	0.547	0.584

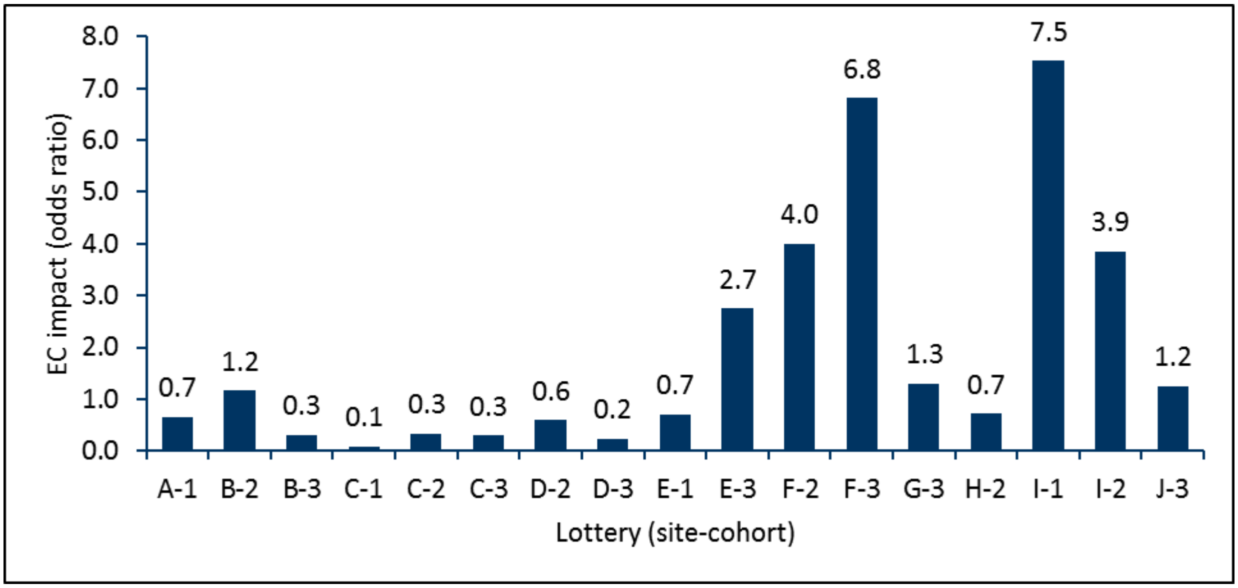
Note. *N* = 2,458 (1,044 EC, 1,414 control).

Exhibit G-5. Lottery-Specific EC Impact on Completion of Any Degree by Year 10 Based on a Random-Effects Model



Note. *N* = 2,458 (1,044 EC, 1,414 control).

Exhibit G-6. Lottery-Specific EC Impact on Completion of an Associate's Degree or Certificate by Year 10 Based on a Random-Effects Model



Note. *N* = 2,458 (1,044 EC, 1,414 control).

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