Dual-Credit Courses and the Road to College: Experimental Evidence from Tennessee

Steven W. Hemelt
Nathaniel L. Schwartz
Susan M. Dynarski

Abstract

Dual-credit courses expose high school students to college-level content and provide the opportunity to earn college credits, in part to smooth the transition to college. With the Tennessee Department of Education, we conduct the first randomized controlled trial of the effects of dual-credit math coursework on a range of high school and college outcomes. We find that the dual-credit advanced algebra course alters students' subsequent high school math course-taking, reducing enrollment in remedial math and boosting enrollment in precalculus and Advanced Placement math courses. We fail to detect an effect of the dual-credit math course on overall rates of college enrollment. However, the course induces some students to choose four-year universities instead of two-year colleges, particularly for those in the middle of the math achievement distribution and those first exposed to the opportunity to take the course in eleventh rather than twelfth grade. We see limited evidence of improvements in early math performance during college. © 2019 by the Association for Public Policy Analysis and Management.

INTRODUCTION

A growing proportion of jobs across the United States require training beyond the high school level (Carnevale, Smith, & Strohl, 2013; Holzer, 2012). Moreover, evidence suggests that the labor market is becoming increasingly bifurcated, with non-college-educated workers moving out of middle-skills jobs and into low-wage, service-oriented work (Autor, 2010).

Policy debates regarding pathways to success beyond high school raise concerns about too few students enrolling in higher education (Carnevale & Rose, 2011, 2015), insufficient preparation among those who do enroll (Lewin, 2014; Scott-Clayton, 2018), and the affordability of college (Folbre, 2013; Looney & Lee, 2018). Such conversations have catalyzed policy innovations that blur the boundary between high school and college. These innovations have taken myriad forms—from early college high schools (Edmunds et al., 2013) to a range of partnerships between high schools, community colleges, universities, and state departments of education (Adams, 2013; Courrégé, 2012).

In this paper, we study one such innovation: state-created, dual-credit courses in Tennessee. These courses are developed by teams of high school teachers and college instructors of the same subject. The teams produce standards aligned to college-level expectations and content, which are then delivered through courses taught by high school teachers within the walls of Tennessee high schools. High school teachers

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receive summer training before offering dual-credit courses and students have the opportunity to earn college credits based on their performance on an end-of-course exam. We unpack these elements of Tennessee's dual-credit courses more below, but note here the conceptual kinship they share with elements of Advanced Placement (AP) coursework.

AP courses are administered by the College Board and taught by high school teachers who are trained to deliver a nationally standardized, college-level curriculum in a particular subject area. Between 2003 and 2013, the number of students who took an AP exam roughly doubled, from 514,000 to over one million (College Board, 2014). Students only receive college credit for an AP course if they take the optional end-of-course exam and earn a passing score (typically 3 or above out of 5); however, the minimum score required for college credit varies by college and AP exam subject (Smith, Hurwitz, & Avery, 2017). Advocates of the continued expansion of AP courses see this standardization as a way to ensure curricular consistency and portability of any postsecondary credits earned. Critics point to historically lower rates of AP course enrollment and exam-taking by minority and low-income students compared to their white and more affluent peers (Klopfenstein, 2004; Malkus, 2016).[1] While AP courses have long been available to high-achieving students, recent concerns about educational preparation and the shifting labor market tend to focus on the stock of middle-achieving students on the margin of college attendance as well as those traditionally underrepresented in institutions of higher learning.

Dual-credit courses are one form of early postsecondary opportunities that attempt to target the high school experiences of such students. Outside of the highly structured model of early college high schools (Edmunds et al., 2017), there is little conclusive evidence of causal effects of early postsecondary experiences on late high school and early college outcomes, including remediation, college enrollment, choice, and persistence (Bailey & Karp, 2003; Lerner & Brand, 2006).[2] On the specific question of the efficacy of dual-credit courses, there is very little research. Existing work largely focuses on dual-enrollment courses (e.g., An, 2013; Giani, Alexander, & Reyes, 2014; Karp et al., 2007; Speroni, 2011a, 2011b) and often begins with samples of college enrollees, thereby leaving unexplored the effects of such experiences on college enrollment and choice (e.g., An, 2013). We partnered with the Tennessee Department of Education (TDOE) to randomize the rollout of one of the pilot dual-credit courses, advanced algebra, in order to learn about the ways in which such courses shape students' educational progression.

To preview results, we see little evidence that dual-credit math courses function as competitors for AP math courses. Instead, these courses tend to attract somewhat different types of students, with the dual-credit advanced algebra course drawing enrollees from across the top three-quarters of the statewide baseline performance distribution. Participation in the dual-credit advanced algebra course alters students' subsequent math course-taking trajectories during late high school, reducing

[1] The College Board has made recent efforts to reduce the AP participation gap between high-income and low-income students by waiving exam fees and has encouraged schools to improve access to AP courses for minority students (College Board, 2014). For a recent, wider review of the literature on AP courses, consult Smith, Hurwitz, and Avery (2017).

[2] An exception is quasi-experimental research linking participation in AP courses to increases in college attendance (Jackson, 2010). Since AP courses are designed for high-achieving students, these findings may not generalize to dual-credit programs aimed at a broader swath of students. More broadly, evidence suggests that alignment of high school and postsecondary expectations in conjunction with providing high school juniors with information about their levels of college readiness reduces the need for remediation in college (Howell, Kurlaender, & Grodsky, 2010). A related but distinct strand of work has explored effects of pre-college advising interventions on postsecondary enrollment (e.g., Bettinger & Evans, 2019; Oreopoulos & Ford, 2019).

the likelihood of enrollment in remedial math and boosting enrollment in more rigorous math courses such as precalculus and AP math courses. We also find some evidence that enrollment in the dual-credit math course increases the likelihood of subsequently passing an AP math exam.

We fail to detect an effect of the dual-credit math course on overall rates of college enrollment, but find that the course tilts students' choices away from two-year colleges and toward four-year universities. This substitution in college choices is clearest for students in the middle 50 percent of the statewide baseline achievement distribution and those first exposed to the opportunity to enroll in the course in eleventh grade. Among college-goers in that middle-achieving group, we find that participation in the dual-credit math course reduces the likelihood of withdrawing from a college-level math course within one year of high school completion. However, apart from this finding, we see little evidence of improvements in early math performance during college due to enrollment in the dual-credit high school math course.

The paper unfolds as follows: In the next section, we describe the Tennessee policy context from which the dual-credit initiative arose and then detail specific elements of the dual-credit math course. The third section describes the data and our empirical approach. The fourth section presents the main results. The fifth section discusses implementation in schools and costs of the dual-credit initiative. The sixth section concludes.

TENNESSEE POLICY CONTEXT AND DUAL-CREDIT EXPERIMENT

Early Postsecondary Opportunities in Tennessee

Recent Tennessee legislation (Public Chapter [PC] 967, 2012) created a consortium of state agencies charged with expanding "early postsecondary education opportunities" for high school students across the state. The consortium, led by the chancellor of the Tennessee Board of Regents (TBR) and the president of the University of Tennessee system, includes representatives from the State Board of Education, the TDOE, and the Tennessee Higher Education Commission (THEC). The legislation also established (within TDOE) the Office of Postsecondary Coordination and Alignment to oversee implementation efforts.

The dual-credit policy was the first major initiative to emerge from PC 967. To carry out the dual-credit policy, the Office of Postsecondary Coordination and Alignment assembled committees of high school and college instructors to draft standards that would align high school courses with college expectations. One of these committees developed the college-algebra standards and standardized test used in the treatment schools in our study. The Office of Research and Policy and the Office of Postsecondary Coordination and Alignment worked together with the authors to design this experiment and recruit schools for the study.[3]

The dual-credit initiative fit into Tennessee's overarching desire to expand the suite of early postsecondary opportunities available to high school students (O'Hara, 2009). Prior to this legislation, there had been little to no systematic expansion of dual-credit (or dual-enrollment) opportunities for high school students in Tennessee.[4] In 2008, several colleges sought state approval for dual-enrollment arrangements with specific high schools. Half of these pilot programs did not survive the

[3] We discuss details regarding eligibility and randomization in the subsequent section.
[4] Further, AP and International Baccalaureate (IB) courses have not been heavily used in Tennessee over the past few years. For example, in 2007/2008, Tennessee ranked 35th out of all states in the number of AP tests per eleventh and twelfth graders (O'Hara, 2009).

year (O'Hara, 2009). The Tennessee Education Lottery Scholarship Dual Enrollment Grants provide funding for eleventh and twelfth graders to take college courses, but these do not completely cover the costs of such courses.

Tennessee's dual-credit courses are free to students. The TDOE covers the end-of-course exam fee (TDOE, 2017). By state statute, all of Tennessee's public colleges and universities are required to grant degree-bearing credit to students who pass the exam.[5] On these dimensions, Tennessee has hewn to the recommendations of a recent report on the experience with dual enrollment in California, including making the credits consistent and portable, allowing for broad student eligibility, and providing professional development to dual-credit instructors (Hughes et al., 2012, pp. 39–40). Because of these design elements, we hypothesize that statewide dual-credit courses will affect the behavior of students who would be dissuaded by the financial, scheduling, and procedural barriers of dual enrollment.

Broadly, Tennessee's dual-credit courses aim to combine the portability and curricular standardization of AP courses with the flexibility and regional flavor of dual-enrollment[6] partnerships between high schools and local postsecondary institutions. In comparison to AP, dual-credit programs are more varied in their course offerings (e.g., academic or vocational) and criteria for college-level credit (Borden et al., 2013; Karp et al., 2007). In 2010/2011, 82 percent of public high schools across the country offered dual-credit courses, with enrollment in such courses topping two million students (Thomas et al., 2013). Dual-credit programs differ widely between (and even within) states where secondary and postsecondary institutions work to coordinate credit transferability and course access policies (Taylor, Borden, & Park, 2015).

Supporters of broadening the reach of dual-credit courses contend that the development of such courses creates "structural" reform to the secondary-postsecondary pipeline, by more explicitly encouraging closer collaboration and coordination between high schools and colleges (Karp, 2015). Further, they praise the capacity of dual-credit course offerings to reflect local educational strengths and labor markets as well as target students traditionally underrepresented in higher education (An, 2013; Karp, 2015; Karp et al., 2007).

Critics point to the difficulty of policing the quality of dual-credit courses.[7] Moreover, there is concern that widening access to early postsecondary opportunities may set up middle- and low-achieving students for failure, since the typical high school student may not be able to handle college-level work (Bailey & Karp, 2003).

The specific course of interest in this study, dual-credit college algebra, targets students in eleventh and twelfth grades and focuses on advanced algebraic concepts and applications. Evidence indicates that students struggle with math in late high

[5] In practice, in-state private institutions also accepted passing scores for college credit (P. Watson, Tennessee Department of Education, personal communication, October 9, 2017).

[6] Though often quite different in structure, "dual credit" and "dual enrollment" are frequently used interchangeably by policymakers, educators, and researchers (Allen, 2010; Borden et al., 2013; Cowan & Goldhaber, 2015; Hoffman, Vargas, & Santos, 2009). More specifically, "dual credit" is often used as an umbrella term that encompasses courses taken in high school that include the opportunity to earn college credit, as well as courses taken on the campuses of postsecondary institutions that may also count for high school credit. Though we use "dual credit" in its umbrella sense in our review of prior work, in our study's context the term "dual credit" refers to courses offered within the walls of high school in which there is an opportunity for students to also earn college credit (for the same course). Thus, "dual enrollment" refers to instances where students attend classes on college campuses, in which college-specific credit is a function of course performance and high school credit varies by the nature of the local partnership between high schools and colleges.

[7] The National Alliance of Concurrent Enrollment Partnerships (NACEP) is largely a response to this concern. It accredits "high-quality" dual-credit and dual-enrollment programs based on a set of criteria established by the organization. For more information, see http://www.nacep.org/about-nacep/.

Table 1. Elements of treatment versus control contrast.

Dimension	Treatment Schools	Control Schools
Math Course Offerings	Dual-credit advanced algebra and trigonometry (AAT); other math courses	Regular, non-dual-credit advanced algebra and trigonometry (AAT); other math courses
AAT Standards	Aligned to postsecondary expectations by working group of high school and college mathematics instructors; shared among all AAT teachers in treatment schools	Varied, school-/district-specific curricula
AAT Teacher Support	Summer training (2 days) and access to online network of dual-credit AAT educators to share resources and lessons learned	No additional training or professional development
AAT Exam	Required, end-of-course exam (centrally graded for possible college credit)	Regular, teacher-/school-specific exams; no opportunity for college credit

school and early college, with many of them ending up in remediation. Among high school graduates entering college in 2003/2004, 39 percent took a remedial math course. Perhaps because of this initial hurdle (Jenkins, Smith Jaggers, & Roksa, 2009), only 65 percent of students take math in college. Of those who do take math, the median of earned credits is three, out of an attempted six (Table 5 in NCES, 2012). Thus, there is considerable room for improvement in the math performance of late high school and early college students.

Description of Intervention

At its core, the intervention is a new course, randomized at the school level. This treatment includes a number of components. In Table 1, we summarize the treatment-control contrast encountered by students in our study. We distill this contrast by showing differences along several dimensions.

High schools in the control condition have historically offered a course known as Advanced Algebra and Trigonometry (AAT) that covered many of the topics included in a typical college algebra course. However, offerings of and standards for this course differed between schools and there were no standardized assessments.

Teachers in schools in the treatment condition were provided with and trained on a new set of college-algebra course standards developed by a team of the state's secondary and postsecondary math instructors.[8] The standardized course was taught within the existing frame of the school's AAT course during the 2013/2014 and

[8] Most treated high schools trained only one math teacher to teach the dual-credit course. In 2013/2014, 81 percent of treated schools had just one dual-credit advanced algebra teacher; this figure declined slightly in the second year to 70 percent, with a few more schools housing two math teachers trained to teach the dual-credit course.

2014/2015 academic years. Therefore, once randomized to treatment and control conditions, study schools remained in those conditions for two academic years—during which time different sets of students passed through classrooms. No additional prerequisites were imposed on students in order to take the course beyond whatever held at baseline.

At the treatment schools, the course was aligned with standards agreed upon by high school and college mathematics instructors in Tennessee.[9] Teachers at treatment schools (in both cohorts) were provided with information and training on these standards, as well as assistance in aligning their courses with them. The training consisted of two days of professional development targeting the alignment of the high schools' AAT course with colleges' College Algebra standards.[10]

Students in the new (dual-credit) algebra course were required to take a centrally graded, standardized, end-of-course exam. Those who performed above a minimum score on this exam could claim credit (upon enrollment) at any public college in Tennessee.[11]

Schools in the control condition were not able to send teachers to the summer trainings. Similarly, students in control schools were not permitted to take the standardized, end-of-course assessment that is part of the treatment.

DATA AND METHODS

Randomization

In early spring 2013, TDOE solicited interest from Tennessee's high schools in offering the new dual-credit AAT course. In order to demonstrate committed interest, school leaders were required to sign a memorandum of understanding (MOU) with the state that outlined elements of participation in the dual-credit pilot. On this form, principals of interested schools also had to identify at least one math teacher who could attend the summer trainings and teach the dual-credit AAT course in 2013/2014. In total, 105 high schools submitted the necessary forms to be eligible for the pilot, constituting slightly less than one-third of the state's public high schools. Two of these schools were so new that they had no baseline data, and so were excluded from randomization, leaving a sample of 103 high schools.

We implemented a blocked, school-level randomization. Tennessee is divided into three geographic regions (west, central, and east) that differ in their high school student bodies, cultures, and college-going rates. Therefore, we blocked on region and then randomized schools to treatment and control conditions within each region. Randomization resulted in 53 treatment schools and 50 control schools.

Data Sources and Analytic Sample

We primarily use data from Tennessee's State Longitudinal Data System (SLDS), known as "MeasureTN." This system contains information on all students in

[9] See Appendix B for materials regarding these standards. All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at http://onlinelibrary.wiley.com.

[10] In both the summers of 2013 and 2014, teachers were able to choose from several training dates and locations. The state covered teachers' attendance expenses. During the training that led into the 2014/2015 academic year, treatment teachers were also given access to an online network of dual-credit AAT teachers across Tennessee for the entirety of the coming academic year. Conversations with state officials suggest that teachers used this network to share resources, assignments, and lessons learned.

[11] The cutoff for both cohorts was 75/100.

Tennessee public schools. We use student-level information on demographics, course-taking, and standardized test scores. We rely on three sources of postsecondary data: First, we use data from THEC that are organized at the student-institution-semester level and capture any student who touches a Tennessee public institution. Second, we incorporate data from TBR that include measures of math course-taking for students at four-year and two-year public institutions governed by TBR. This group includes six of the state's public four-year institutions and all public two-year institutions (n = 13).[12] These two sources of data allow us to richly characterize the postsecondary experiences of students who enroll in public institutions within the state of Tennessee. Finally, we use data from the National Student Clearinghouse (NSC) to capture students who enroll in private and out-of-state institutions.[13]

Our first challenge is to identify the population of high school students exposed to the dual-credit intervention. To do so, we begin by examining traditional math course progressions of all Tennessee high school students. Looking at recent cohorts of graduates (i.e., 2013, 2014), the Office of Research and Policy (ORP) in the TDOE found substantial variation in math courses taken by students in eleventh and twelfth grades (ORP, 2015). However, during the first two years of high school, many students took Algebra I, Geometry, or Algebra II.[14]

When we focus on the students in 2013/2014 (across the entire state) who populate our course of interest, Advanced Algebra and Trigonometry (AAT), we notice two things about this group. First, the vast majority are juniors and seniors in high school. Second, 96 percent of first-time AAT enrollees had completed Algebra II and 89 percent had taken Geometry. Using these descriptive findings as guideposts, we define "exposure" as any student who had taken Algebra II or Geometry or both by the start of academic year *t* (e.g., 2013/2014, 2014/2015).[15] We apply this rule across both treatment and control schools to arrive at a sample of students who were reasonably positioned to enroll in the new, dual-credit AAT course.[16] We further restrict the sample to students in grades 11 or 12 in the year in which they were first exposed to the opportunity to take the new dual-credit math course. In total, our analytic sample contains 61,766 students, with 42,098 first exposed in 2013/2014 and 19,668 first exposed in 2014/2015.[17]

[12] During the years of our study, the six universities included in the TBR data are Middle Tennessee State University, University of Memphis, Tennessee Technological University, Austin Peay State University, Tennessee State University, and East Tennessee State University. The four branches that comprise the University of Tennessee system are not governed by the TBR.

[13] TDOE and THEC submit cohorts of high school graduates to the NSC to measure rates of immediate college enrollment and choice. Based on data for the past few cohorts of high school graduates, about 90 percent of all college-going students attended an in-state college—and 90 percent of those in-state enrollees appeared at public institutions. Thus, we privilege the richer data we have on students' postsecondary experiences at Tennessee public institutions in the construction of our outcomes. In addition, NSC data capture over 95 percent of all students enrolled in private non-profit institutions in Tennessee during our time period (NSC, Enrollment Coverage Workbook, 2017).

[14] We observe the same patterns of math course-taking in our student-level data.

[15] A survey of available course syllabi from high schools also revealed that common prerequisites for the AAT course were Algebra II, Geometry, or both.

[16] We do not allow concurrent enrollment in Algebra II or Geometry to satisfy the exposure rule since the exposed population should be able to be identified with information available before the treatment occurs. Once the new dual-credit AAT course is running in treatment schools, dynamics of course-taking may be different relative to control schools. Each student appears only once in our final sample and is associated with the academic year (or "cohort") in which she first met our exposure rule. Overall, our preferred exposure rule captures over 95 percent of students enrolled in AAT in our sample of high schools during the 2013/2014 and 2014/2015 academic years.

[17] We address within-year, across-school movement as well as across-year, across-school movement of students in this assignment process. For a student who moves between schools within an academic year,

To explore differences in treatment and control courses, we use information from a survey of teachers in the 2014/2015 academic year.[18] We identified a total of 114 teachers with AAT courses in this year, 55 treatment and 59 control.[19] We sent all teachers in this population an introductory letter from the principal investigators outlining the study and the importance of the survey to come. The mailing included a $10 Amazon gift card.[20] Next, we sent e-mails that contained individual links to the appropriate (treatment or control) survey. After a few weeks, graduate research assistants followed up with non-respondents by e-mail and telephone calls (to non-respondents' schools). The overall response rate was 78 percent, with treatment teachers responding at a higher rate than control teachers: 89 percent and 68 percent, respectively.

Analytic Approach

Based on the randomization process described above, schools initially assigned to the treatment condition were supposed to offer the dual-credit advanced algebra course within the school's existing "AAT" course frame/number. Even with the MOU, not all treatment schools did so. Six schools (11 percent of the treatment group) failed to offer the dual-credit course during the first year (2013/2014). In the second year of the pilot (2014/2015), one of those six schools offered the dual-credit course and an additional seven schools dropped out, which resulted in about 24 percent of the original treatment group of schools failing to offer the dual-credit advanced algebra course in 2014/2015. None of the control schools offered course sections of dual-credit AAT. A small number of students initially sitting in control schools gained access to dual-credit AAT at treatment schools.[21] These on-the-ground realities inform our analytic approach.

We use initial randomization at the school level to isolate exogenous variation in (a) a school offering at least one section of dual-credit advanced algebra; and (b)

we base her treatment status on the school in which we see her taking the most classes in the fall of that academic year. Similarly, for a student we observe in both 2013/2014 and 2014/2015 and who moves schools across cohorts, we base her treatment assignment on the school in which we see her in the fall of 2013.

[18] Please consult Appendix C for paper copies of treatment and control teacher surveys. All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at http://onlinelibrary.wiley.com.

[19] The purpose of the survey is to measure differences in dual-credit AAT compared to non-dual-credit AAT. We identified treatment and control teachers as a function of schools' initial assignments via randomization in conjunction with knowledge about schools' prior participation in the treatment and information on AAT course offerings. We identified five teachers in schools that were originally assigned to the treatment group but promptly dropped out of treatment. Therefore, since these schools never implemented any elements of the treatment, teachers taught the regular, non-dual-credit version of AAT. Accordingly, we sent these five teachers the control version of the survey. They are included in the 59 control teachers. Our patterns of findings are very similar if we reclassify these teachers as treatment or if we drop their observations from the analytic sample.

[20] We developed our survey protocol based on the recent findings of Jacob and Jacob (2012). The authors found that including a monetary incentive in advance of a survey substantially increased the response rate of principals, relative to the no-incentive condition.

[21] This occurred through simultaneous enrollment: A student in a control school would dually enroll in a treated section of advanced algebra in a treatment school. This phenomenon is rare: In 2013/2014, 43 students in control schools took a dual-credit version of AAT (at a treatment school). The near totality of these cases (41/43) is accounted for by a set of two geographically proximate schools (in a particular region of Tennessee). By chance, one of those schools was assigned to the treatment group and the other to the control group. Each of these schools allows students to enroll in classes at the other. Thus, the treatment school refused to bar interested students from the control school from enrolling in the dual-credit advanced algebra course. In 2014/2015, eight students assigned to control schools managed to enroll in dual-credit AAT at a treatment school. Our results are unchanged if we drop these 51 students from the analytic sample.

a student enrolling in dual-credit advanced algebra.[22] We then use this exogenous variation to identify the effects of (a) and (b) on a range of educational outcomes. We do so through the use of two-stage least squares (2SLS) estimators that reflect the following basic setup:

$$DCAA_{sb} = \mu + \lambda_1 T_{sb} + \varphi X_{isbc} + \kappa Z_{sb} + \delta_{bc} + \nu_{isbc} \tag{1}$$

$$Y_{isbc} = \alpha + \beta_1 \widehat{DCAA}_{sb} + \rho X_{isbc} + \phi Z_{sb} + \delta_{bc} + \varepsilon_{isbc}. \tag{2}$$

Here, T_{sb} is equal to one if school s in regional block b was randomized to the treatment condition at the start of the experiment, and zero otherwise. The outcome variable in the first-stage (equation (1)), $DCAA_{sb}$, equals one if school s in regional block b offered at least one section of dual-credit college algebra during the pilot period, and zero otherwise.[23] Within this setup, λ_1 represents the take-up or compliance rate and β_1 represents the causal effect of a school offering at least one section of dual-credit advanced algebra on an outcome of interest, Y_{isbc}. We include region-by-cohort indicators (δ_{bc}) to adjust for the blocked-randomization procedure. We also include a vector of student-level covariates (X_{isbc}) including race and ethnicity, gender, grade level, and prior math test scores as well as school-level measures that capture the demographic and achievement profiles of schools in the base year of 2013/2014 (Z_{sb}) to improve precision;[24] ν_{isbc} and ε_{isbc} are stochastic error terms. We cluster standard errors at the school level to adjust for the nesting of students within schools.

When we estimate the effects of a student enrolling in dual-credit advanced algebra, we replace $DCAA_{sb}$ with its student-level analogue, $DCAA_{isb}$, which takes on a value of one if a student enrolled in dual-credit advanced algebra during the pilot period, and zero otherwise. As above with the school-level treatment effects, we can also estimate cohort-specific student-level treatment effects (e.g., effect of student enrolling in dual-credit advanced algebra during the 2013/2014 academic year). Patterns of cohort-specific effects mirror the pooled estimates.

The school- and student-level treatment effects are conceptually and empirically related. The effect of a school offering at least one section of dual-credit advanced algebra on an outcome equals the share of exposed students induced to enroll in the dual-credit math course as a consequence of the school's initial randomization

[22] We can also estimate a first-stage model where the outcome indicates whether a student passed the challenge exam associated with the dual-credit advanced algebra course. Pass rates are quite low and therefore we have little power within our experimental setup with which to detect the effect of a student passing the challenge exam on postsecondary outcomes. In 2013/2014, the pass rate was 12 percent; in 2014/2015, it was 36 percent. In complementary work, we are pooling challenge exam scores across several dual-credit courses in different subject areas and using a regression-discontinuity (RD) approach to examine the effect of passing a challenge exam on measures of early postsecondary success and progress (e.g., credits earned in first semester of college).

[23] We also estimate variants of this first-stage setup in which we add a cohort subscript to DCAA, thereby exploring the relationship between original assignment to treatment and whether a school offered at least one section of dual-credit advanced algebra in 2013/2014 (cohort 1) or 2014/2015 (cohort 2).

[24] Given that the treatment is assigned at the school level, this is the key level of identifying variation. In addition, we can control for the school-level share of students eligible for free or reduced-price meals (FARM) using publicly available data even though Tennessee law does not permit us to use the student-level FARM indicator in our analyses. We include all of the school-level controls listed in Table A1 except for the "school success score," since it is an older index from 2011/2012 and since we can directly include the performance components of that index from 2013/2014 as controls (i.e., shares of students proficient in Algebra, English, and Biology). The inclusion of these school-level aggregates improves the precision of our estimates but does not meaningfully alter coefficient estimates or patterns of findings. All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at http://onlinelibrary.wiley.com.

to treatment multiplied by the effect of enrolling in the dual-credit course on that outcome for the typical student. We anchor our discussion of most results on the effects of a school offering at least one section of dual-credit advanced algebra for two reasons. First, since the treatment was randomized at the school level, that is the level at which we have the greatest power to detect effects. Second, the school-level treatment effect strikes us as more policy relevant, since a school cannot compel a student to enroll in a dual-credit course—but it can certainly choose to offer that course.[25]

FINDINGS

Descriptive Statistics and Baseline Balance

Table 2 presents descriptive statistics on the students in our analytic sample and assesses baseline balance between students in treatment and control schools. We see clear evidence of a functional experiment. There are no meaningful differences in students' demographics or prior math achievement across treatment and control groups at baseline. Further, we observe no differences in measures of high school performance or school size across treatment and control schools at baseline. Indeed, a joint test of the statistical relationship between all baseline measures and treatment status produces a p-value of 0.83, indicating that we are unable to reject the null hypothesis that the means of these baseline characteristics are the same for exposed students in treatment and control schools.[26]

In total, the analytic sample is about half male, 80 percent white, 12 percent black, and 5 percent Hispanic. The majority of students in our analytic sample are in eleventh grade at the start of the academic year in which they were first exposed to the opportunity to take the dual-credit math course. The typical student in our analytic sample scored 0.19 standard deviations above the statewide average on her Algebra I end-of-course test.[27]

Table A1 compares the set of schools that comprise our experimental sample to all public schools in Tennessee that serve traditional high school grades (i.e., 9 to 12) as well as the subset of that full population that did not show interest in the pilot.[28] Compared to the subset of schools that did not indicate interest in the

[25] A third reason is that since no control schools offered a dual-credit section of the math course, we can interpret our 2SLS estimates at the school level as treatment-on-the-treated (TOT) effects, which have slightly wider applicability than their cousin, the local average treatment effect (LATE)—see Angrist and Pischke (2009) for a lucid, detailed discussion of this topic.

[26] Given that schools remain in their control conditions for two academic years, 2013/2014 and 2014/2015, one might be concerned that students in a school randomly assigned to treatment in 2013/2014 might adjust their math course-taking in a manner that would make them more likely to meet our exposure rule in 2014/2015 than their counterparts in control schools. To explore this concern, we take all non-twelfth graders in treatment and control schools in the 2013/2014 academic year and estimate the intent-to-treat (ITT) effect of a school's initial assignment to treatment on the likelihood a student first meets our exposure rule in the 2014/2015 academic year. The point estimate and standard error on the variable indicating initial randomization to the treatment group are -0.005(0.008). Thus, this result assuages such concerns.

[27] The students in our analytic sample ought to be moderately higher performing relative to all high school students in the state since the exposure rule restricts the sample to those who have completed Algebra II or Geometry by the start of the academic year. We limit the analytic sample to students with non-missing Algebra I end-of-course test scores. Results are identical if we retain students with missing test scores and control for missing values with indicator variables in our regressions. Only 5 percent of students in the full sample are missing Algebra I test scores—and this share does not differ across treatment and control groups; it is 5 percent in each.

[28] All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at http://onlinelibrary.wiley.com.

Table 2. Descriptive statistics and baseline balance.

Variable	Full Sample	Treatment Group	Control Group	T - C Difference	Adjusted p-value
Demographics					
Male	0.501	0.504	0.499	0.006	0.299
White, Non-Hispanic	0.797	0.819	0.776	0.043	0.230
Black, Non-Hispanic	0.123	0.109	0.136	–0.028	0.262
Asian, Non-Hispanic	0.014	0.013	0.015	–0.002	0.607
Hispanic	0.052	0.046	0.057	–0.010	0.492
Other Race/Ethnicity, Non-Hispanic	0.015	0.013	0.016	–0.002	0.595
English Language Learner (ELL)	0.057	0.049	0.065	–0.017	0.391
Grade Level in Year of First Exposure					
11th	0.626	0.624	0.629	–0.005	0.509
12th	0.374	0.376	0.371	0.005	0.509
Algebra End-of-Course (EOC) Performance					
Algebra I EOC Score, standardized	0.188 (0.876)	0.191 (0.879)	0.185 (0.874)	0.006	0.959
Range: –3.22 – 2.93					
Prior Math Courses					
Took Algebra II	0.087	0.076	0.097	–0.020	0.496
Took Geometry	0.501	0.500	0.503	–0.003	0.718
Took Algebra II and Geometry	0.412	0.424	0.401	0.023	0.556
School Characteristics					
Total Enrollment	1318 (534)	1304 (562)	1332 (506)	–28	0.840
Range: 98 – 2336					
Share Proficient in Algebra I	67.53 (12.24)	66.18 (13.29)	68.81 (11.00)	–2.63	0.276
Range: 29.5 – 98.9					
Share Proficient in Biology	67.20 (13.39)	67.01 (14.78)	67.39 (11.90)	–0.37	0.962
Range: 21.7 – 96.5					
Share Proficient in English I	74.52 (10.88)	74.31 (12.31)	74.72 (9.32)	–0.41	0.919
Range: 30.8 – 99.2					
Missing Any Subject Proficiency	0.016	0.026	0.006	0.020	0.447
Overall F-test of all observables	–	–	–	–	0.832
N(students)	61,766	30,359	31,407		
N(schools)	103	53	50		

Notes: Standard deviations appear in parentheses for continuous variables. Adjusted p-values come from simple regressions where the outcome is the covariate of interest and the independent variables include the treatment indicator and region-by-cohort effects. The p-value for the overall F-test of all observables comes from jointly testing the significance of the full set of baseline covariates in the context of one regression model, where the outcome is the treatment indicator (which denotes whether a student appeared in a treatment school). Standard errors are clustered at the school level. See text for details about assigning students to schools.

Table 3. First-stage results: Dual-credit advanced algebra.

A. School Offerings

	School offers at least one section of dual-credit AAT		
Independent variable	Ever (1)	During 2013/2014 (2)	During 2014/2015 (3)
Treatment school	0.893***	0.875***	0.812***
	(0.046)	(0.047)	(0.051)
N(students)	61,766	61,766	61,766
R-squared	0.837	0.819	0.752
F-stat for treatment status indicator	380.0	348.9	253.0

B. Student Enrollment and Success

	Student enrolls in dual-credit AAT		
Independent variable	Ever (4)	During 2013/2014 (5)	During 2014/2015 (6)
Treatment school	0.120***	0.064***	0.057***
	(0.010)	(0.007)	(0.006)
N(students)	61,766	61,766	61,766
R-squared	0.108	0.074	0.065
F-stat for treatment status indicator	151.8	86.2	95.8
	Student passes dual-credit AAT challenge exam		
Independent variable	Ever (7)	During 2013/2014 (8)	During 2014/2015 (9)
Treatment school	0.025***	0.009***	0.017***
	(0.004)	(0.002)	(0.002)
N(students)	61,766	61,766	61,766
R-squared	0.039	0.019	0.026
F-stat for treatment status indicator	44.9	24.5	53.1

Notes: Sample includes students in eleventh or twelfth grade in year of first exposure to the new dual-credit math course (i.e., 2013/2014 or 2014/2015). "Treatment school" is an indicator that denotes a school's initial assignment to the treatment condition via randomization. All models include baseline demographic and achievement controls described in the text as well as region-by-cohort fixed effects. Robust standard errors clustered at the school level appear in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

pilot study, the schools in our experimental sample are a bit larger, slightly higher achieving, and enroll smaller shares of black students. The achievement differences between these groups of schools are modest. Nevertheless, such comparisons allow the reader to judge the degree to which the findings from our experimental context may generalize to a broader set of high schools.

First-Stage Results: Dual-Credit Course Offerings and Student Enrollment

In Table 3, we present results based on equation (1). In panel A, the outcome denotes whether a school offered at least one section of dual-credit advanced algebra. In panel B, the outcome indicates whether a student enrolled in the dual-credit advanced algebra course; and in panel C the outcome records passage of the challenge exam.

Across both years of the pilot, about 89 percent of schools randomized to the treatment condition offered at least one section of the dual-credit advanced algebra course. Assignment to treatment induced about 12 percent of exposed students to enroll in the dual-credit math course and only 2.5 percent to pass the end-of-course challenge exam.[29] Pass rates among challenge-exam takers increased from 12 to 36 percent between the first and second years of the pilot.

The Offer of a New, Dual-Credit Math Course and Advanced Placement Course-Taking in Mathematics

Armed with a picture of the treatment-control contrast and a sense of take-up by schools and students, we now turn to our first set of findings. Given some of the similarities in design between the new statewide dual-credit math course and Advanced Placement (AP) math courses, we first explore whether the offer of this new, dual-credit advanced algebra course siphoned off would-be AP math students.

To explore this question, we estimate our 2SLS setup specified by equations (1) and (2), focusing on the effect of a school offering at least one section of dual-credit advanced algebra on the likelihood a student enrolls in an AP math course in the same year as well as the likelihood of enrollment in the new, dual-credit math course. Table 4 presents these results.

If availability of the new, dual-credit course were luring students away from AP math courses, we would expect to see negative and statistically significant coefficients on the indicator for the offer of at least one section of the dual-credit math course, especially among students in the top of the baseline, statewide achievement distribution. In Table 4, we see no such evidence. All of our estimates in column 1 are very close to zero in magnitude and statistically insignificant. Moreover, the majority of these null estimates are quite precise. In addition, for students in the top quarter of the baseline achievement distribution, there is some evidence that the offer of the new dual-credit math course increases the likelihood of enrollment in AP Statistics in the year the dual-credit course appeared. The estimates in column 4 illustrate that the new dual-credit course attracted students across the performance distribution, with notable numbers coming from the middle 50 percent of baseline achievement.[30] The fact that the offer of the dual-credit advanced algebra course induced some relatively high-achieving students to take it without compensating declines in AP math course-taking means that other math courses had to have been affected. In ancillary analyses, we explored contemporaneous course-taking effects on other math courses. Students in the top half of the baseline achievement distribution are taking the dual-credit version of AAT rather than its non-dual-credit counterpart.

Taken together, these findings suggest that the new dual-credit math course and existing AP math courses function as complements, attracting somewhat different groups of students. Thus, if other types of dual-credit courses relate in the same manner to existing AP courses, state-developed, dual-credit courses and AP courses could be pursued by school leaders and policymakers as complementary strategies.

[29] The share of exposed students who enrolled in the dual-credit course ranged from a low of 1 percent to a high of 37 percent across treatment schools in the study.

[30] Though the share of exposed students induced to enroll in the dual-credit math course is smaller among the middle 50 percent of the baseline achievement distribution than among the top 25 percent of that distribution, a much larger number of students in the analytic sample fall into that middle 50 percent, thereby suggesting a greater number of dual-credit enrollees from the middle-achieving group.

Table 4. Substitutes or Complements?
The offer of dual-credit advanced algebra and contemporaneous AP math course-taking.

Sample and independent variable	Take AP Math Course in Year of First Exposure to New Dual-Credit Advanced Algebra Course: Any AP Math (1)	AP Calculus (2)	AP Statistics (3)	Take Dual-Credit AAT in Year of First Exposure (4)
All Students (N = 61,766)				
School offers at least one section of dual-credit advanced algebra course	0.005	−0.001	0.008**	0.082***
	(0.006)	(0.004)	(0.004)	(0.008)
Outcome mean for control group	0.03	0.02	0.01	0.00
Middle 50% of baseline statewide achievement distribution (N = 36,993)				
School offers at least one section of dual-credit advanced algebra course	0.002	−0.001	0.002	0.074***
	(0.002)	(0.001)	(0.002)	(0.008)
Outcome mean for control group	0.01	<0.01	<0.01	0.00
Top 25% of baseline statewide achievement distribution (N = 16,894)				
School offers at least one section of dual-credit advanced algebra course	−0.002	−0.015	0.020*	0.149***
	(0.019)	(0.013)	(0.011)	(0.019)
Outcome mean for control group	0.10	0.08	0.03	0.00

Notes: Sample includes students in eleventh or twelfth grade in year of first exposure to the new dual-credit math course (i.e., 2013/2014 or 2014/2015). Estimates come from a two-stage, instrumental variables (IV) approach where a school's original randomized assignment to treatment is used as the instrument in the first stage to predict an endogenous variable of interest (e.g., school offered at least one section of dual-credit advanced algebra). All models include baseline demographic and achievement controls described in the text as well as region-by-cohort fixed effects. We use students' scores on the baseline math assessment, the Algebra I end-of-course (EOC) exam, to form performance subgroups relative to the statewide distribution. Robust standard errors clustered at the school level appear in parentheses. *** p<0.01; ** p<0.05; * p<0.1.

Dual-Credit Advanced Algebra and Subsequent Math Course-Taking in High School

Table 5 presents effects of (a) a school offering at least one section of the dual-credit advanced algebra course and (b) a student enrolling in that course on outcomes that measure course-taking in mathematics during the next year of high school. We restrict the analytic sample to eleventh graders and focus on outcomes that measure participation in courses for which there is a clear hypothesis about possible effects: AP math courses, precalculus, and "Bridge Math," which is a remedial math course targeted at twelfth graders.[31]

On average, we find that the offer of at least one section of the dual-credit math course increases the share of eleventh graders who take an AP math course in their senior year by about 2 percentage points (column 1 of Table 5) and reduces the share who take the remedial math course, "Bridge Math," by about 6 percentage points (column 3 of Table 5), relative to control schools without such a dual-credit

[31] We also looked at other math courses, such as non-AP calculus and statistics courses, as well as "other" infrequently taken math courses. We discuss effects on these classes when relevant for certain subgroups of students, but overall there are few effects of taking dual-credit advanced algebra on subsequent enrollment in these other math courses.

Table 5. Dual-credit advanced algebra and subsequent math course-taking in late high school.

	Take Math Course in Next Academic Year		
Sample and independent variable	Any AP Math (1)	Precalculus (2)	Bridge Math (3)
11th Grade Students (N = 38,675)			
School offers at least one section of dual-credit advanced algebra course	0.020* (0.011)	0.022 (0.016)	−0.063** (0.031)
Student enrolls in dual-credit advanced algebra course	0.152* (0.087)	0.167 (0.124)	−0.481* (0.246)
Outcome mean for control group	0.06	0.09	0.46
11th Graders in middle 50% of baseline statewide achievement distribution (N = 24,371)			
School offers at least one section of dual-credit advanced algebra course	0.006 (0.006)	0.033** (0.016)	−0.097** (0.039)
Student enrolls in dual-credit advanced algebra course	0.051 (0.053)	0.289* (0.148)	−0.840** (0.351)
Outcome mean for control group	0.02	0.07	0.57
11th Graders in top 25% of baseline statewide achievement distribution (N = 10,207)			
School offers at least one section of dual-credit advanced algebra course	0.039 (0.033)	0.028 (0.033)	−0.030* (0.018)
Student enrolls in dual-credit advanced algebra course	0.167 (0.143)	0.055 (0.135)	−0.125 (0.077)
Outcome mean for control group	0.17	0.18	0.13
White, Non-Hispanic 11th Grade Students (N = 30,757)			
School offers at least one section of dual-credit advanced algebra course	0.017 (0.013)	0.017 (0.017)	−0.073** (0.031)
Student enrolls in dual-credit advanced algebra course	0.128 (0.094)	0.130 (0.130)	−0.540** (0.241)
Outcome mean for control group	0.06	0.10	0.44
Black and Hispanic 11th Grade Students (N = 6,736)			
School offers at least one section of dual-credit advanced algebra course	0.020*** (0.008)	0.042*** (0.016)	−0.009 (0.042)
Student enrolls in dual-credit advanced algebra course	0.168*** (0.065)	0.346** (0.142)	−0.072 (0.350)
Outcome mean for control group	0.03	0.08	0.54

Notes: Sample includes students in eleventh grade in year of first exposure to the new dual-credit math course (i.e., 2013/2014 or 2014/2015). Estimates come from a two-stage, instrumental variables (IV) approach where a school's original randomized assignment to treatment is used as the instrument in the first stage to predict an endogenous variable of interest (e.g., school offered at least one section of dual-credit advanced algebra). All models include baseline demographic and achievement controls described in the text as well as region-by-cohort fixed effects. Robust standard errors clustered at the school level appear in parentheses. *** p<0.01; ** p<0.05; * p<0.1; "Bridge Math" is a remedial math course targeted at twelfth graders.

offering. The decrease in the rate of remedial course-taking during late high school represents a 14 percent reduction relative to the control mean.

Because dual-credit courses are touted as a way to expose middle-achieving students and those traditionally underrepresented in higher education to the standards, rigor, and expectations of a college-level course within the familiar walls of high school, we examine heterogeneous effects for policy-relevant demographic subgroups of students. Additional panels in Table 5 present results for subgroups of students defined by baseline achievement level, race and ethnicity. Most coefficients are similar to those for the full sample, suggesting that the benefits of taking dual-credit advanced algebra in terms of subsequent math course-taking are broadly shared across different types of students.[32] However, we highlight the clear effects on subsequent course-taking for black and Hispanic students, a group that has had historically low participation rates in AP math courses. For a student in this subgroup, we find that taking the dual-credit math course increases the likelihood of enrolling in an AP math course in the next year of high school by about 17 percentage points—partially driven by an increased propensity to take AP Statistics. That is the treatment effect for the marginal minority *student*. Consider the related effect of a *school* offering at least one section of the dual-credit advanced algebra course on AP course-taking for this subgroup of students: The offer of at least one section of this course by a school increases the share of black and Hispanic students who take an AP math course in their next year of high school by 2 percentage points. The share of such students who take an AP math course in control schools is 3.2 percent. Thus, an increase in that share of 2 percentage points due to the offer of the dual-credit math course represents a substantial and practically significant treatment effect.[33]

The reduction in the likelihood of taking remedial math during a student's senior year of high school is also widely shared across subgroups, except for black and Hispanic students, for whom there is little effect of dual-credit math on this outcome. Additional estimates show that participation in the dual-credit math course reduces the likelihood that black and Hispanic students take "other" math courses during twelfth grade.[34] The math courses that we grouped into the "other" category are a smattering of less rigorous courses: for example, about 65 percent of the black and Hispanic students in our analytic sample who took an "other" math course during 2014/2015 or 2015/2016 as twelfth graders enrolled in "Finite Math," which is a foundational math course designed to prepare students for college and the workforce.[35] Black and Hispanic students also experience a boost in their likelihood of taking precalculus during twelfth grade as a consequence of participating in the dual-credit algebra course (column 2 of Table 5). Finally, note that eleventh graders in the middle 50 percent of the baseline achievement distribution exhibit the clearest tilt away from the remedial math course and toward precalculus.

Taken together, these findings make clear that the offer of at least one section of the dual-credit math course altered students' course-taking trajectories, shifting them away from the remedial math course and toward more challenging math classes, such as AP math courses and precalculus.

Dual-Credit Advanced Algebra and AP Math Performance

Given the findings that relate participation in the dual-credit math course and subsequent enrollment in AP math courses, a natural next question is whether students'

[32] Patterns of effects of the dual-credit course on subsequent course-taking by gender are very similar.
[33] These student-level and school-level treatment effects are related: To arrive at the student-level effect, we can scale the effect of the offer of at least one section of the dual-credit math course by a school by the share of students induced to enroll in the dual-credit course as a consequence of a school's initial randomization to the treatment group. For example, 11.6 percent of black and Hispanic eleventh graders were induced to enroll in a dual-credit advanced algebra course—thus, $0.020/0.116 = 0.17$, which is approximately the student-level treatment effect of enrolling in the dual-credit advanced algebra course for this subgroup.
[34] Specifically, the offer of at least one section of the dual-credit advanced algebra courses decreases the share of black and Hispanic students who enroll in "other" math courses during twelfth grade by 5 percentage points, compared to control schools.
[35] For more details on this course, please see the TDOE standards here: https://www.tn.gov/content/dam/tn/education/standards/archive/std_arch_math_3182.pdf.

Table 6. Dual-credit advanced algebra and subsequent AP success.

	Earn score of 3 or higher in next academic year on . . .		
Sample and independent variable	Any AP Math Test (1)	AP Calculus Test (2)	AP Statistics Test (3)
11th Grade Students (N = 38,675)			
School offers at least one section of dual-credit advanced algebra course	0.007 (0.005)	0.002 (0.004)	0.008*** (0.003)
Student enrolls in dual-credit advanced algebra course	0.053 (0.036)	0.019 (0.028)	0.061** (0.024)
Outcome mean for control group	0.02	0.02	<0.01
11th Graders in middle 50% of baseline statewide achievement distribution (N = 24,371)			
School offers at least one section of dual-credit advanced algebra course	−0.001 (0.001)	−0.001 (0.001)	0.000 (0.001)
Student enrolls in dual-credit advanced algebra course	−0.004 (0.007)	−0.008 (0.006)	0.003 (0.006)
Outcome mean for control group	0.01	<0.01	<0.01
11th Graders in top 25% of baseline statewide achievement distribution (N = 10,207)			
School offers at least one section of dual-credit advanced algebra course	0.017 (0.014)	0.001 (0.011)	0.026*** (0.009)
Student enrolls in dual-credit advanced algebra course	0.070 (0.061)	0.005 (0.047)	0.112** (0.045)
Outcome mean for control group	0.06	0.05	0.02
White, Non-Hispanic 11th Grade Students (N = 30,757)			
School offers at least one section of dual-credit advanced algebra course	0.007 (0.005)	0.002 (0.004)	0.009*** (0.003)
Student enrolls in dual-credit advanced algebra course	0.050 (0.036)	0.012 (0.028)	0.065*** (0.025)
Outcome mean for control group	0.02	0.02	<0.01
Black and Hispanic 11th Grade Students (N = 6,736)			
School offers at least one section of dual-credit advanced algebra course	0.004* (0.002)	0.002 (0.002)	0.002 (0.002)
Student enrolls in dual-credit advanced algebra course	0.033* (0.020)	0.015 (0.015)	0.016 (0.013)
Outcome mean for control group	<0.01	<0.01	<0.01

Notes: Sample includes students in eleventh grade in year of first exposure to the new dual-credit math course (i.e., 2013/2014 or 2014/2015). Estimates come from a two-stage, instrumental variables (IV) approach where a school's original randomized assignment to treatment is used as the instrument in the first stage to predict an endogenous variable of interest (e.g., school offered at least one section of dual-credit advanced algebra). All models include baseline demographic and achievement controls described in the text as well as region-by-cohort fixed effects. Robust standard errors clustered at the school level appear in parentheses. *** $p<0.01$; ** $p<0.05$; * $p<0.1$.

experiences in the dual-credit course better prepare them to succeed on the end-of-course AP exams. Many colleges award credit for scores of 3 or higher on AP exams (which are scored out of 5).

Table 6 presents these results. We find clear evidence that participation in the dual-credit advanced algebra course during eleventh grade increases the likelihood of scoring a 3 or higher on the AP Statistics exam during twelfth grade. This boost is concentrated among students in the top 25 percent of the baseline achievement distribution and white, non-Hispanic eleventh graders. However, black and Hispanic students see a more generalized increase in the likelihood of passing any AP math exam (i.e., Calculus or Statistics). For a student in this subgroup, enrollment in the dual-credit math course increases the likelihood of passing any AP math exam by about 3 percentage points.[36] Conditional on taking any AP math course, the proportion of black and Hispanic students in control schools who score at least a 3 on an AP math exam is 13 percent, a figure that is less than half the pass rate for white, AP math enrollees in control schools (37 percent).

Taken together, the results in Tables 5 and 6 suggest that participation in the dual-credit advanced algebra course boosted the likelihood students in traditionally disadvantaged minority groups went on to enroll and succeed in AP math courses. In addition, the pattern and direction of estimates for other subgroups across Tables 5 and 6 suggest that middle-achieving students experienced a push toward precalculus in twelfth grade and that higher-achievers saw a boost in their likelihood of passing the AP Statistics exam.

In the next sections, we examine how effects on these measures of course-taking in late high school translate, if at all, into effects on college enrollment and choice. Given that our sample consists of eleventh and twelfth graders and that the majority of dropout occurs before these upper high school grades, we did not expect to find meaningful effects of participation in the dual-credit math course on high school graduation. Table A2 supports this hypothesis.[37]

Dual-Credit Advanced Algebra, College Enrollment, and College Choice

Table 7 presents results that examine the effect of a school offering at least one section of the dual-credit advanced algebra course on measures of college-going and choice.[38] For economy of presentation and exposition, we report only the school-level treatment effects in Table 7, but refer the reader to Table A3 for the analogous student-level results. We fail to detect a statistically significant effect of the dual-credit math course on overall rates of college enrollment within one year of expected, on-time high school graduation.[39]

In terms of college choice, we find that the dual-credit advanced algebra course reduces the likelihood of attending a two-year institution, on average and for nearly

[36] This is an unconditional effect; that is, a student who does not enroll in any AP math courses during her subsequent year of high school receives a zero for this outcome. Thus, the effect we detect is partially due to the increased propensity of black and Hispanic students to enroll in an AP math course. One cannot take an AP exam without enrolling in the course.

[37] The null effect of the dual-credit math course on high school graduation also assuages any concerns one might have about our supplementary use of the NSC data to construct some of our postsecondary outcomes, given that Tennessee submits cohorts of high school graduates to the NSC. All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at http://onlinelibrary.wiley.com.

[38] The postsecondary data that we have assembled from several sources described earlier in the paper go up to the fall semester of 2016. Thus, the analytic sample that we use to explore effects on postsecondary outcomes is restricted to students for whom we can capture college enrollment within one year of expected, on-time high school graduation. Point estimates are very similar, and patterns of findings are unchanged if we re-specify our outcomes to capture only one semester's worth of time following expected, on-time high school graduation.

[39] In addition, we detect no effect of the dual-credit course on enrollment in a postsecondary institution within the boundaries of Tennessee compared to an out-of-state institution. Nearly 85 percent of college-going students in our analytic sample first attend an in-state institution. Further, among those in-state college-goers, the vast majority attend public institutions.

Table 7. Dual-credit advanced algebra, college enrollment, and college choice.

		Subgroup					
Treatment and Outcome	All Students (1)	Middle 50% Baseline Achievement Distribution (2)	Top 25% Baseline Achievement Distribution (3)	First exposed in 11th Grade (4)	First exposed in 12th Grade (5)	White, Non-Hispanic (6)	Black and Hispanic (7)
Treatment = School offers at least one section of dual-credit advanced algebra course							
Enroll in 4-year institution (NSC + THEC)	0.026* (0.015)	0.035** (0.016)	0.018 (0.023)	0.035** (0.017)	0.019 (0.016)	0.027 (0.017)	0.027 (0.016)
Outcome mean for control group	0.33	0.25	0.61	0.33	0.33	0.33	0.30
Enroll in 2-year institution (NSC + THEC)	−0.034** (0.014)	−0.033** (0.015)	−0.026 (0.019)	−0.050*** (0.016)	−0.018 (0.015)	−0.034** (0.016)	−0.027* (0.015)
Outcome mean for control group	0.27	0.32	0.23	0.31	0.24	0.29	0.23
Enroll in any college (NSC + THEC)	−0.005 (0.012)	0.002 (0.016)	−0.002 (0.010)	−0.014 (0.013)	0.003 (0.013)	−0.005 (0.014)	0.002 (0.014)
Outcome mean for control group	0.61	0.58	0.84	0.65	0.58	0.63	0.54
Enroll in TBR-covered institution (THEC)	−0.019 (0.016)	0.001 (0.015)	−0.016 (0.015)	−0.035* (0.019)	−0.004 (0.015)	−0.020 (0.019)	−0.007 (0.015)
Outcome mean for control group	0.36	0.38	0.39	0.39	0.33	0.36	0.35
N(students)	43,839	24,790	13,242	20,998	22,841	35,168	7,502

Notes: Sample includes students whose expected, on-time graduation year (as a function of their audited ninth grade cohort year) is 2013/2014 or 2014/2015 and who were in eleventh or twelfth grade when first exposed to the opportunity to take the dual-credit math course. Postsecondary outcomes are measured within one year of expected, on-time high school graduation; and outcomes that capture choice refer to the first institution in which a student enrolls during that period. Estimates in this table come from a two-stage, instrumental variables (IV) approach where a school's original randomized assignment to treatment is used as the instrument in the first stage to predict an endogenous variable of interest (e.g., school offered at least one section of dual-credit advanced algebra). All models include baseline demographic and achievement controls described in the text as well as region-by-cohort fixed effects. Robust standard errors clustered at the school level appear in parentheses. *** $p<0.01$; ** $p<0.05$; * $p<0.1$; NSC = National Student Clearinghouse; THEC = Tennessee Higher Education Commission; TBR = Tennessee Board of Regents.

all subgroups, with an offsetting increase in the propensity to attend a four-year university (which includes both publics and privates).[40]

The tilt away from two-year colleges and toward four-year universities is clearest for students in the middle 50 percent of the statewide, baseline achievement distribution and those who were first exposed to the opportunity to take the dual-credit math course in eleventh grade. In combination with earlier findings that demonstrated an upgrade in the level of math courses taken in twelfth grade as a consequence of participating in the dual-credit algebra course in eleventh grade, these results support a human capital story, wherein the dual-credit course improved students' math skills, strengthened their 12th-grade experiences with mathematics, and tilted their college choices away from two-year colleges and toward four-year institutions. Note that estimates for those first exposed to the dual-credit course in twelfth grade are smaller and weaker, relative to estimates for those first exposed in eleventh grade. Estimates across subgroups defined by race and ethnicity are very similar to the average effects for all students, suggesting that the shift away from two-year and toward four-year institutions is broadly shared across such subgroups.

In the final row of Table 7, we present estimates of the effect of the dual-credit advanced algebra course on enrollment in public institutions covered by the Tennessee Board of Regents (TBR). Recall that TBR-member institutions include all public two-year institutions and six of the public four-year institutions in the state of Tennessee. These are the institutions from which we have course-level data and can measure performance in math courses early in students' college careers. Thus, understanding how our treatment shapes the choice to attend a TBR institution can help with interpreting any performance effects we uncover, conditional on a student appearing in a TBR institution. We see limited evidence that the offer of the dual-credit math course reduced the likelihood of enrollment in a TBR-covered institution, perhaps with the exception of students first exposed to the opportunity to take the dual-credit course in eleventh grade.

Dual-Credit Advanced Algebra and Early Postsecondary Math Performance

Table 8 examines the effect of the offer of the dual-credit advanced algebra course on early college progress and performance.[41] In panel A, we use data from THEC organized at the student-institution-semester level to construct outcomes that measure credit accumulation. In panel B, we use course-level data from TBR to construct outcomes that measure early college performance in mathematics. The latter data only contain math courses and capture students at institutions governed by TBR during the time of our study, which included all public two-year colleges and six public four-year institutions. Thus, the analytic sample for panel A is restricted to those who enroll in a Tennessee public institution within one year of expected, on-time high school graduation. Similarly, the analytic sample for panel B is restricted to students who enroll in a TBR-covered institution within one year of expected, on-time high school graduation. Therefore, any effects we find are conditional on

[40] Conversations with staff members in the Office of Postsecondary Coordination and Alignment at the TDOE confirmed that many private institutions in the state of Tennessee also accepted passing scores on the end-of-course challenge exams associated with dual-credit courses for college credit—even though they were not bound to do so by state statute. In addition, we see no effect of the dual-credit course on enrollment in Tennessee's technical colleges (https://www.tbr.edu/institutions/colleges-applied-technology).

[41] Table A4 presents analogous estimates of the effect of a student enrolling in the dual-credit advanced algebra course on measures of early postsecondary performance in math. All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at http://onlinelibrary.wiley.com.

Table 8. Dual-credit advanced algebra and early college success.

Outcome Domain, Treatment, Outcomes	All Students (1)	Subgroup: Middle 50% Baseline Achievement Distribution (2)	Top 25% Baseline Achievement Distribution (3)	First exposed in 11th Grade (4)	First exposed in 12th Grade (5)	White, Non-Hispanic (6)	Black and Hispanic (7)
A. Credit Accumulation							
Treatment = School offers at least one section of dual-credit advanced algebra course							
Number of credits earned within year following expected, on-time HS graduation (THEC)	0.305 (0.509)	0.113 (0.549)	0.982 (0.698)	0.331 (0.602)	0.318 (0.523)	0.429 (0.556)	0.051 (0.671)
Outcome mean for control group	22.4	19.2	29.3	22.5	22.3	23.2	18.1
Earn 30 or more credits within year following expected, on-time HS graduation (THEC)	0.008 (0.015)	0.005 (0.016)	0.020 (0.022)	0.010 (0.016)	0.007 (0.018)	0.012 (0.017)	0.002 (0.020)
Outcome mean for control group	0.34	0.22	0.56	0.34	0.33	0.36	0.19
B. Performance in College Math Courses							
Treatment = School offers at least one section of dual-credit advanced algebra course							
Enroll in at least one math course within year following expected, on-time HS graduation (TBR)	0.002 (0.017)	−0.002 (0.018)	0.007 (0.023)	0.003 (0.021)	0.005 (0.018)	0.000 (0.018)	0.016 (0.033)
Outcome mean for control group	0.69	0.70	0.68	0.66	0.72	0.68	0.71
Pass at least one math course within year following expected, on-time HS graduation (TBR)	0.010 (0.016)	0.008 (0.017)	0.010 (0.026)	0.002 (0.018)	0.019 (0.017)	0.008 (0.017)	0.022 (0.026)

Table 8. Continued.

Outcome Domain, Treatment, Outcomes	All Students (1)	Subgroup: Middle 50% Baseline Achievement Distribution (2)	Top 25% Baseline Achievement Distribution (3)	First exposed in 11th Grade (4)	First exposed in 12th Grade (5)	White, Non-Hispanic (6)	Black and Hispanic (7)
Outcome mean for control group	0.50	0.49	0.57	0.48	0.52	0.51	0.46
Withdraw from at least one math course within year following expected, on-time HS graduation (TBR)	−0.010	−0.015**	0.001	−0.007	−0.013	−0.012*	0.004
	(0.007)	(0.008)	(0.007)	(0.007)	(0.009)	(0.007)	(0.014)
Outcome mean for control group	0.06	0.07	0.05	0.07	0.06	0.06	0.07
N(students) - THEC sample	20,069	11,222	7,540	10,322	9,747	16,425	3,060
N(students) - TBR sample	15,259	9,362	4,837	7,855	7,404	12,236	2,614

Notes: The analytic sample for outcomes in panel A includes students whose expected, on-time graduation year (as a function of their audited ninth grade cohort year) is 2013/2014 or 2014/2015, were in eleventh or twelfth grade when first exposed to the opportunity to take the dual-credit math course, and attended a Tennessee public institution of any kind within one year of expected, on-time high school graduation. Measures of cumulative credits include courses taken during summer terms. The analytic sample for outcomes in panel B is the subset of students in the analytic sample for panel A who enroll in a two-year or four-year public institution covered by TBR in the year following expected, on-time high school graduation. Course-based outcomes include information from courses taken in summer terms. Estimates in this table come from a two-stage, instrumental variables (IV) approach where a school's original randomized assignment to treatment is used as the instrument in the first stage to predict an endogenous variable of interest (e.g., school offered at least one section of dual-credit advanced algebra). All models include baseline demographic and achievement controls described in the text as well as region-by-cohort fixed effects. Robust standard errors clustered at the school level appear in parentheses. *** p<0.01; ** p<0.05; * p<0.1; THEC = Tennessee Higher Education Commission; TBR = Tennessee Board of Regents.

enrollment in these sectors and partially reflect any effects of the dual-credit math course on college choices.

In terms of credit accumulation, we find little. For example, we find no evidence that the dual-credit advanced algebra course increases the share of students who earn 30 or more credits during the year following expected, on-time graduation from high school—which is a benchmark for progress toward timely degree completion. We similarly find no effect of the dual-credit math course on the total number of college credits students accumulate over that year-long horizon.

In terms of early math performance in college, we find that middle-achieving students at baseline are about 1.5 percentage points (21 percent) less likely to withdraw from a college-level math class during the year following high school due to participation in the dual-credit math course. However, aside from that finding, we see limited evidence of improvements in early college math performance.[42] Some of the other estimates are suggestive of a possible beneficial effect of the dual-credit algebra course on taking and passing a college-level math course, such as those for black and Hispanic students. However, the estimates are noisy, and none rise to conventional levels of statistical significance, thereby precluding strong conclusions. Once again, since the treatment influenced students' choices of colleges, we must interpret these results on performance conditional on attending a TBR-member institution with caution.

Inside the Black Box: Survey-Based Comparisons of Treatment and Control Classroom Conditions

Thus far, we have learned that the dual-credit math course shifted students' course-taking in late high school away from remedial math courses and toward higher-level mathematics. The treatment did not influence overall rates of college-going, but did shift students, especially middle-achieving students, into four-year universities. Though we cannot parse and test all possible mechanisms through which these effects may have emerged, in this section we use data from a survey of classroom teachers in treatment and control schools to characterize some of the key ways the treatment may have altered students' classroom experiences. Specifically, we pair survey data collected from teachers in 2014/2015 with administrative data on teachers to characterize the treatment-control differences in the classroom experiences of students.

We first use administrative data to explore differences in basic teacher characteristics across treatment and control conditions. To do so, we link teachers to math courses and find those teaching AAT in 2014/2015. This is the group of teachers to whom we sent the survey. We then merge on basic demographic and professional information about those teachers, such as age, years of teaching experience, and gender. In addition, we add measures of prior experience teaching a range of math courses. We use course data from the 2012/2013 academic year to get a sense of teachers' prior experiences with different math courses before the new dual-credit course was on the scene.[43]

Table 9 compares average characteristics of treatment and control teachers for two samples: first, the full set of teachers who received the survey; and second, the

[42] We also examined effects of dual-credit advanced algebra on the likelihood of earning a grade of C or higher (and B or higher) in a college-level math course during the year following high school, as well as the effect on a student's GPA in her postsecondary math courses during that year, finding little.
[43] Indeed, roughly 70 percent of teachers in both the control and treatment groups taught AAT in the prior academic year, which was the first year of the experimental pilot.

Table 9. Teacher characteristics, treatment-control contrast, and survey response.

	AAT Teachers in study schools, 2013/2014				AAT Teachers who responded to survey			
Variable	Treatment Mean (SD) (1)	Control Mean (SD) (2)	T-C Difference (3)	p-value (4)	Treatment Mean (SD) (5)	Control Mean (SD) (6)	T-C Difference (7)	p-value (8)
A. Demographics								
White	0.93	0.95	−0.02	0.85	0.92	0.95	−0.03	0.61
Black	0.02	0.02	0.00	0.87	0.02	0.00	0.02	0.37
Race is missing	0.05	0.02	0.03	0.55	0.06	0.03	0.03	0.51
Male	0.39	0.36	0.03	0.74	0.37	0.36	0.01	0.89
Gender is missing	0.05	0.02	0.03	0.55	0.06	0.03	0.03	0.51
Age as of Sept 1, 2014	44.19	43.45	0.74	0.75	44.06	43.60	0.46	0.87
	(10.92)	(11.42)			(10.89)	(12.13)		
Age missing	0.05	0.05	0.00	0.78	0.06	0.05	0.01	0.96
B. General Experience								
Number of years teaching	15.62	15.96	−0.34	0.75	15.42	17.08	−1.66	0.43
	(8.15)	(11.57)			(8.51)	(12.84)		
Teacher experience missing	0.05	0.02	0.03	0.55	0.06	0.03	0.03	0.51
C. Educational Attainment								
Highest degree - Bachelor's	0.27	0.31	−0.04	0.62	0.28	0.33	−0.05	0.54
Highest degree - Master's or Master's Plus	0.59	0.55	0.04	0.55	0.59	0.54	0.05	0.60
Highest degree - EDS or PhD	0.09	0.12	−0.03	0.56	0.08	0.10	−0.02	0.70
Degree information is missing	0.05	0.02	0.03	0.55	0.06	0.03	0.03	0.51
D. Math Course Experience, 2012/2013								
Taught AAT	0.41	0.57	−0.16	0.09	0.35	0.46	−0.11	0.29
Taught Algebra I	0.27	0.24	0.03	0.61	0.29	0.21	0.08	0.33
Taught Algebra II	0.51	0.45	0.06	0.39	0.53	0.49	0.04	0.65
Taught Geometry	0.27	0.22	0.05	0.49	0.24	0.23	0.01	0.95
Taught Precalculus or Calculus	0.42	0.33	0.09	0.37	0.41	0.33	0.08	0.46
Taught Bridge Math	0.14	0.05	0.09	0.10	0.16	0.03	0.13	0.04
Taught Other Math Course	0.17	0.07	0.10	0.16	0.12	0.05	0.07	0.30
No course information	0.10	0.12	−0.02	0.47	0.12	0.15	−0.03	0.63
Share responded to survey	0.87	0.67	0.20	0.01	–	–	–	–
N(teachers)	59	58			51	39		

Notes: Adjusted differences control for geographic region (west, central, east) of teacher's school. Treatment and control statuses of teachers are based on schools' initial assignments via randomization, knowledge of prior treatment take-up, and information on AAT course offerings in schools. See text for details on creation of sample for teacher survey. SD = standard deviation; EDS status is considered equivalent to a doctorate for salary purposes: https://www.tn.gov/education/topic/update-license-information.

subset of survey recipients who responded.[44] Patterns are similar across the two panels. These comparisons allow us to assess the degree to which any effects of the new dual-credit advanced algebra course on late high school and early college outcomes might reflect differences in the type of teacher who taught the dual-credit version of the course compared to the "regular," non-dual-credit version. That is, if teachers with more experience teaching algebra-heavy courses or simply more years of general teaching experience were more likely to teach the "treatment" version of the AAT course, this would shape our interpretation of any treatment effects—that is, they would not solely be due to differences in practices, standards, assignments, and other elements reflected in Table 1, but also to attributes of the teacher.

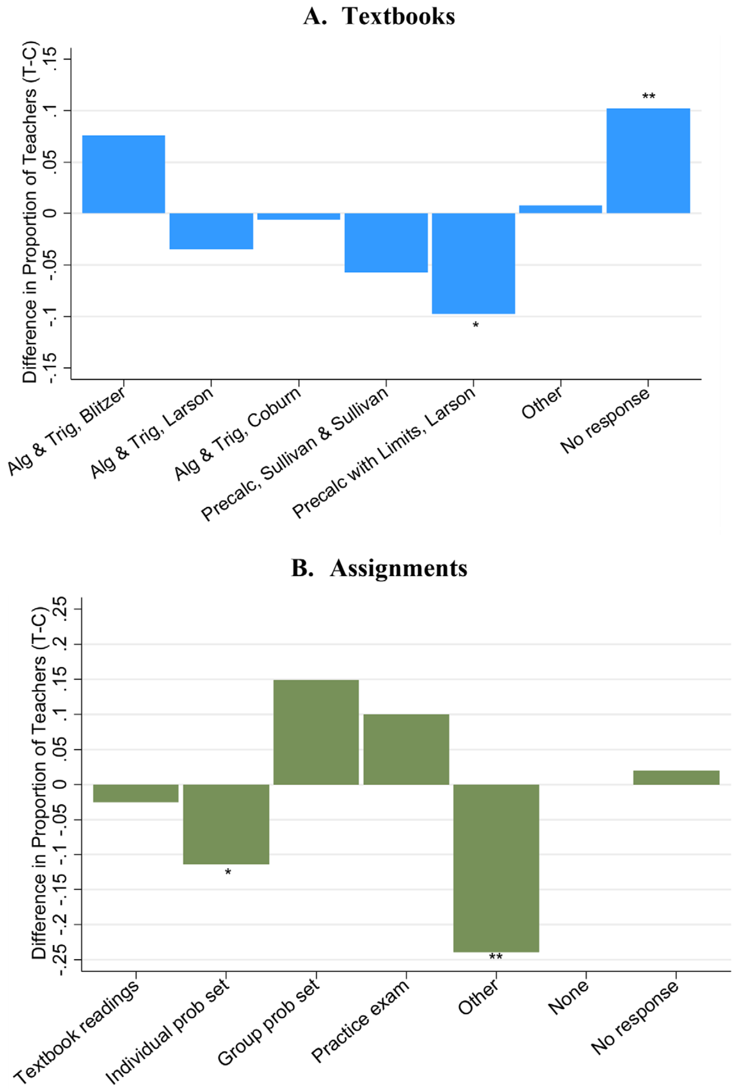
There are no notable differences across treatment and control teachers in terms of demographics, teaching experience, or educational attainment. In terms of math-course-specific experience (panel D of Table 9), the profiles of treatment and control teachers look largely similar. However, the share of treatment teachers who report teaching AAT in 2012/2013 is moderately lower than the share of control teachers who report doing so. In addition, higher shares of treatment teachers report experience across a range of other math courses, including those that precede AAT in sequencing, such as Algebra I, Algebra II, and Geometry. Taken together, this suggests that teachers in the dual-credit version of AAT were drawn from a slightly wider swath of prior math courses, compared to teachers in the "regular," non-dual-credit version of AAT.

We now turn to an exploration of survey-based differences in the characteristics of treatment and control classes. In Figure 1, we show differences in the textbooks and assignments used by AAT teachers in treatment schools relative to their counterparts in control schools. Panel A of Figure 1 depicts differences in the texts preferred by dual-credit AAT teachers compared to their non-dual-credit counterparts. Treatment teachers were less likely to use the precalculus texts and less likely to respond to this particular survey question.

Panel B of Figure 1 uncovers differences in the types of assignments used by treatment and control teachers. Unsurprisingly, treatment teachers were more likely to use practice exams.[45] In addition, treatment teachers were more likely to have students work in groups on problem sets, whereas control teachers tended to have students work individually on problem sets. We speculate that this difference is driven, at least in part, by the summer trainings for treatment teachers. These trainings included a substantial amount of time for teachers to work in groups developing problems and sharing creative problem-set ideas. It seems that those exercises influenced the practice of treatment teachers in their classrooms. Finally, treatment teachers are much less likely to report using "other" types of assignments, compared to control teachers. Some of the "other" assignments frequently listed by control teachers include worksheets, quizzes, and "supplementary material."

[44] Table A5 uses basic information available in Tennessee's administrative data to explore whether there is a relationship between observable characteristics of the teachers to whom we sent survey invitations and response. Though treatment teachers were substantially more likely to respond to the survey than control teachers, we fail to detect meaningful associations between measures of teaching experience, age, and educational attainment and the likelihood of responding to the survey. Further, among respondents, this same set of observable characteristics fails to predict survey completion—and treatment teachers were as likely to finish the survey as their control peers. Conditional on responding, 92 percent of teachers completed the survey. All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at http://onlinelibrary.wiley.com.

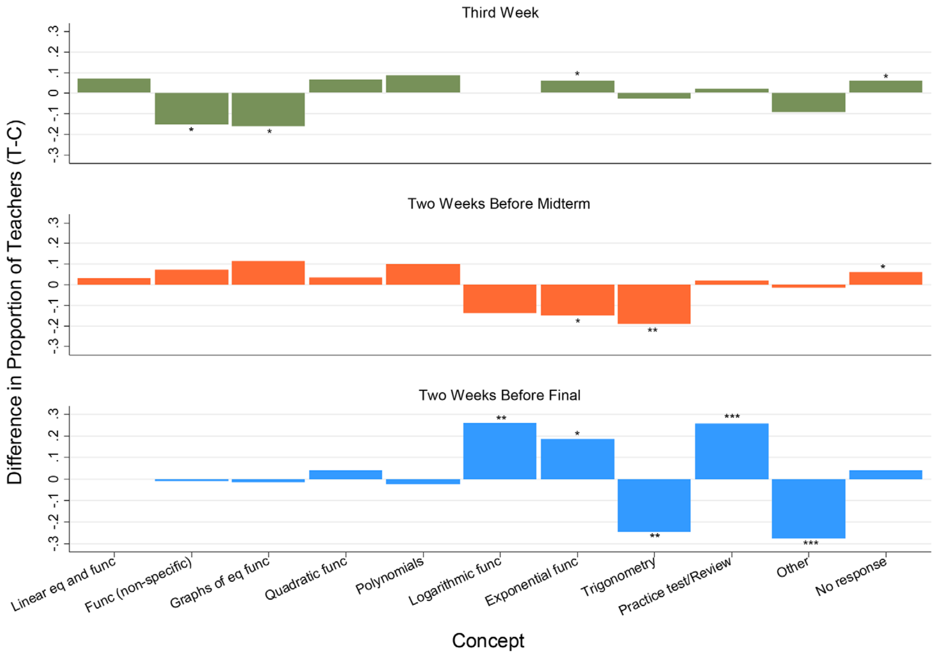
[45] This contrast is especially stark two weeks prior to the final, when treatment teachers are a statistically significant 27 percentage points more likely to use practice exams, relative to control teachers.



Notes: Differences are based on respondents who finished the survey. Information about assignments comes from a question in which teachers could select from the buckets of assignment types listed across the x-axis. Proportions presented here for assignments reflect what teachers were using three weeks into the course, though patterns are very similar if we instead use responses from "two weeks before midterm" or "two weeks before final." ** p<0.05; * p<0.10.

Figure 1. Treatment-Control Differences in Textbook Adoption and Assignment Types.
[Color figure can be viewed at wileyonlinelibrary.com]

One part of the teacher survey asked teachers to sit down with their syllabus or lesson planner and record the concepts they were covering at three time points in the AAT course: the third full week, two weeks prior to the midterm, and two weeks prior to the final exam. These questions were structured as free response. We grouped answers to this set of questions into nine bins. These bins of concepts are listed in loose sequential order along the x-axis of Figure 2. The three panels report



Notes: Differences are based on respondents who finished the survey. Information about concept coverage comes from free-response questions. See text for details about coding of free-form responses. Results are very similar if we limit the sample to teachers who taught a year-long version of the course. *** p<0.01; ** p<0.05; * p<0.10.

Figure 2. Treatment-Control Differences in Timing of Concept Coverage. [Color figure can be viewed at wileyonlinelibrary.com]

treatment minus control differences in the proportion of teachers who responded that they were covering a given concept during the time point indicated by the panel titles. Broadly, we see that treatment teachers were covering certain concepts at different points in time, relative to their counterparts in control classes.

We highlight three aspects of this broad finding: First, treatment teachers were more likely to cover "functions (non-specific)" as well as "graphs of equations and functions" closer to the middle of the course, whereas control teachers tended to cover these concepts near the beginning of the course. Second, treatment teachers were more likely to cover "logarithmic functions" and "exponential functions" near the end of the course, whereas control teachers more often covered such concepts in the middle of the course. Finally, treatment teachers were substantially more likely to conduct test practice and review near the end of the course and much less likely to cover "trigonometry" concepts at any time point, relative to their control counterparts. This last finding is consistent with the fact that the college-aligned standards for the dual-credit version of the AAT course did not include trigonometry.[46] Thus, the patterns in Figure 2 are consistent with treatment teachers spreading out deeper versions and extensions of concepts introduced in Algebra I and Algebra

[46] Recall that Appendix B provides the list of learning objectives for the dual-credit version of the AAT course (often referred to as "Dual-Credit College Algebra"). All appendices are available at the end of this article as it appears in JPAM online. Go to the publisher's website and use the search engine to locate the article at http://onlinelibrary.wiley.com.

II classes. In contrast, control teachers of AAT had to cover more material (including trigonometric concepts). Indeed, control teachers were more likely to cover "trigonometry" and "other"[47] concepts across the three time points in the course.

Taken together, the rich descriptive findings about teachers and their classroom practices suggest that the effects of the dual-credit math course at least partially emanate from differences between treatment and control classrooms in the concepts covered, the pacing and timing of those concepts, and the types of assignments and texts used by teachers. Thus, one reasonable conclusion is that the alignment of standards to the postsecondary level generated greater standardization of curricular materials and concepts within treatment classrooms relative to control classrooms, which in turn enhanced students' math skills and knowledge, better preparing them for advanced math courses later in high school and signaling capacity for enrollment in four-year universities.

DISCUSSION

In this section, we first highlight a few findings related to the character of implementation in schools and then discuss the costs of the dual-credit math course. The typical high school in the experimental sample offered one or two sections of AAT, with 92 percent of schools offering less than five sections. Schools in the treatment condition were required to offer a dual-credit advanced algebra course in the slot (and using the course code) that was previously used for the regular AAT course. However, treatment schools were not explicitly required to convert all of their AAT course sections to dual-credit versions. Using data on students who took the challenge exam at the end of the dual-credit course, we identified "treated" sections of AAT—meaning that these sections were dual-credit sections. Here, we use that information to tally the number of treatment schools that offered (a) exclusively dual-credit versions of AAT and (b) a mix of dual-credit and non-dual-credit AAT sections. In the first year of the pilot, 2013/2014, there were 47 treatment schools that offered at least one dual-credit section of the advanced algebra course.[48] The vast majority of those 47 offered exclusively dual-credit versions of AAT (81 percent) and nine schools (19 percent) offered a mix of dual-credit and non-dual-credit sections of AAT. In 2014/2015, 39 treatment schools offered dual-credit AAT, with 59 percent of those schools offering exclusively dual-credit sections of AAT. These implementation realities partially guided our decision to focus on the effect of a school offering at least one section of dual-credit AAT during the pilot period. It is an easily understandable, communicable, and relevant parameter that subsumes these various flavors of implementation.

In treated courses, all students were supposed to take the end-of-course "challenge" exam for possible college credit. We calculate student-level "noncompliance" rates for each treatment school in our study, by year. In 2013/2014, in 27 of the 47 treatment schools that offered dual-credit advanced algebra, all students in dual-credit sections of the course took the challenge exam, as required by the state (i.e., 54 percent of treatment schools). Among the other 20 schools, the average share of students who appeared in a dual-credit section of AAT and failed to take the challenge exam was low, at 8.5 percent (i.e., about five to six students). In 2014/2015, only 15 percent of treatment schools that offered dual-credit advanced algebra had zero noncompliant students (i.e., six out of 39 schools). Among the remaining 33

[47] Concepts listed by control teachers in the "Other" section included conics, matrices, polar coordinates, and vectors.
[48] Recall that six of the initial 53 schools randomized to treatment failed to offer dual-credit advanced algebra in the first year of the pilot, leaving 47 treatment schools that offered the course in 2013/2014.

Table 10. Costs of dual-credit advanced algebra in Tennessee.

Cost Category and Basic Components	2013/2014	2014/2015	Total
Course Development			
Lead faculty stipend	$18,329	$0	$18,329
Faculty work group meetings			
Professional Development			
Trainer and participant reimbursement	$13,384	$3,783	$17,167
Training facilities			
Exam Administration			
Fee for taking exam	$0	$15,400	$15,400
Total	$31,713	$19,183	$50,896
Total number of challenge exam takers	2,257	2,104	4,361
Cost per exam taker	$14.05	$9.12	$11.67

Source: Tennessee Department of Education.
Notes: In 2013/2014, the test vendor did not charge the state for exam administration. In the second year, the state covered the cost of exam fees for all students. Costs are expressed in nominal dollars.

treatment schools, the average share of students who enrolled in a dual-credit section of AAT and failed to sit for the challenge exam was 12.3 percent (i.e., about eight students). Thus, overall, even when treatment schools failed to ensure that all students enrolled in the dual-credit advanced algebra course took the challenge exam, average rates of such student-level noncompliance were quite low. We speculate that these relatively high rates of exam compliance stem from the fact that students stood to earn college credit based on their exam performance and that the exams were centrally and electronically graded.

We collected information on the costs of developing and delivering the dual-credit advanced algebra course. Table 10 presents these costs divided into three categories: course development, professional development, and exam administration. In the last row of this table, we compute the average cost per student who took the challenge exam. Across the two years of the pilot, this figure amounts to about $12 per exam-taker, a modest cost. For existing courses, the main categories of recurring costs are professional training for teachers and exam administration. Thus, the average cost per exam-taker in the second year of the pilot is only $9. Moving forward, Tennessee will continue to cover the exam administration fee for students taking any dual-credit course (TDOE, 2017).

Relative to other types of programs that have shaped students' decisions about college choice, namely financial aid programs, the cost per student of a statewide dual-credit course pales in comparison. For example, Bruce and Carruthers (2014) found that reductions in college costs for middle-achieving students in Tennessee via a merit-based scholarship program did not influence overall rates of college-going, but rather tilted college enrollment choices toward four-year institutions and away from two-year institutions. The scholarship program provided up to $6,000 per year for students attending in-state four-year institutions (public and private), and up to $3,000 per year for students at in-state public two-year colleges (Bruce & Carruthers, 2014, p. 31). On net, the authors concluded that roughly $4,000 in aid per student-year resulted in a 2 to 3 percentage point shift from two-year colleges to four-year universities. Our estimate of the effect of a school offering at least one section of dual-credit advanced algebra on the shift from two-year to four-year colleges is comparable in magnitude. Table 7 presents these estimates. Taken together, these findings suggest that financial aid is not the only vehicle through which college choices of middle-achieving high school students can be shaped.

Indeed, our findings suggest that channels other than the financial were at work in the effects on college choice that we observe: pass rates on the challenge exam tied to the dual-credit math course were low, but for the subgroups for whom we see the clearest tilt away from two-year public institutions and toward four-year universities, both public and private, we also see that participation in the dual-credit math course boosted the likelihood of taking more rigorous math courses in late high school.

CONCLUSION

The growth of early postsecondary opportunities for high school students across the United States provides fertile ground for researchers and policymakers to partner in understanding the effects of such initiatives on educational and social outcomes of interest. In this paper, we partnered with the state of Tennessee to conduct the first randomized controlled trial of a state-created, dual-credit mathematics course. We find that the offer of this dual-credit course did not dissuade top-performing students from enrolling in Advanced Placement math courses. Rather, the dual-credit advanced algebra course attracted a range of students, including sizeable numbers of students from the middle and upper-middle parts of the statewide baseline achievement distribution—suggesting that AP courses and state-created dual-credit courses could function as complementary strategies.

One of the clearest findings to emerge from this work is that the offer of the dual-credit advanced algebra course altered students' math course-taking trajectories during late high school, shifting students away from remedial or lower-level options and toward more advanced math courses. Specifically, among eleventh graders, we find a large negative effect of participating in the dual-credit math course on the likelihood a student enrolls in a remedial math course during her subsequent year of high school. Rather than enroll in that developmental math course, students enroll in precalculus or AP math courses.

We fail to detect effects of participation in the dual-credit course on overall rates of college-going. Though we see little movement along this extensive margin, we find that the dual-credit advanced algebra course tilted students' college choices away from two-year colleges and toward four-year universities, both public and private. This substitution is clearest for middle-achieving students and those first exposed to the opportunity to enroll in the dual-credit algebra course in eleventh grade. The nature of this choice effect is particularly striking when one considers the surrounding policy context of Tennessee during this time. The first class of high school graduates eligible to take part in the Tennessee Promise, a statewide program that provides last-dollar aid to every high school graduate making a seamless transition to community college (Carruthers & Fox, 2016), was the class of 2015. The academic year 2014/2015 is the second year of our experimental pilot. We find very similar effects regardless of whether we focus on the effect of a school offering (or a student taking) the dual-credit advanced algebra course during 2013/2014 or 2014/2015. The preferred estimates we present throughout the paper represent the effect of taking the course at any point during the two-year pilot period. Thus, the effects we document do not appear to be sensitive to large, notable changes in the surrounding state policy landscape. Such shifts in college choices could have implications for students' later success. Indeed, recent work has demonstrated that access to four-year colleges boosts rates of bachelor's degree completion for modestly prepared students (Goodman, Hurwitz, & Smith, 2017).

As policymakers and school leaders consider the role of the type of dual-credit course we study in this paper, a key charge for future research is to explore the effects of non-math dual-credit courses on late high school and early postsecondary experiences of students. Dual-credit courses in other areas such as those related to career and technical education are likely to attract different types of students with a range of interests and educational needs.

STEVEN W. HEMELT is an Associate Professor of Public Policy at the University of North Carolina at Chapel Hill, Abernethy Hall, 131 S. Columbia Street, Chapel Hill, NC 27599 (e-mail: hemelt@email.unc.edu).

NATHANIEL L. SCHWARTZ is Chief Research and Strategy Officer at the Tennessee Department of Education, Andrew Johnson Tower, 710 James Robertson Parkway, Nashville, TN 37243 (e-mail: nate.schwartz@tn.gov).

SUSAN M. DYNARSKI is a Professor of Public Policy, Education, and Economics at the University of Michigan, Weill Hall, 735 S. State Street, Ann Arbor, MI 48109 (e-mail: dynarski@umich.edu).

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APPENDIX A

Table A1. Experimental sample versus universe of public high schools in Tennessee, 2013/2014.

Variable	All TN High Schools (1)	TN High Schools in Experiment (2)	TN High Schools Not in Experiment (3)
Demographics			
Male	0.51	0.51	0.52
White, Non-Hispanic	0.67	0.78	0.61
Black, Non-Hispanic	0.24	0.13	0.30
Asian, Non-Hispanic	0.02	0.02	0.02
Hispanic	0.06	0.06	0.06
Other Race/Ethnicity, Non-Hispanic	0.02	0.02	0.02
Limited English Proficient (LEP)	0.06	0.05	0.06
Special education	0.13	0.12	0.14
FARM	0.52	0.45	0.56
Enrollment	1128 (528)	1264 (537)	1056 (509)
Academic Performance			
Algebra I, share proficient	0.64	0.68	0.62
Biology, share proficient	0.64	0.68	0.62
English I, share proficient	0.71	0.75	0.70
School Success Score (2011/2012)	62.26 (13.48)	64.76 (11.45)	60.74 (14.39)
N(schools)	370	103	267

Notes: Most of the school-level demographic variables are constructed using the underlying student-level data, with the exception of the FARM variable. We use publicly available data on FARM, enrollment, and overall school performance. Unless otherwise noted, all data correspond to the 2013/2014 academic year. Any public school that offers traditional high school grades (i.e., 9 through 12) counts as a "high school" for the purposes of this simple comparison of school profiles. Academic proficiency measures are aggregates that are based on number of high school students taking end-of-course assessments in a given year. The "school success score" is an index value that was assigned to every high school by the Tennessee Department of Education; it is a function of test performance and graduation rates. FARM = free or reduced-price meals. Standard deviations for continuous variables appear in parentheses.

Table A2. Dual-credit advanced algebra and high school graduation.

Sample and independent variable	Graduate from high school (1)
11th and 12th Grade Students (N = 61,766)	
School offers at least one section of dual-credit advanced algebra course	−0.002
	(0.007)
Student enrolls in dual-credit advanced algebra course	−0.014
	(0.048)
Outcome mean for control group	0.93
11th Grade Students (N = 38,675)	
School offers at least one section of dual-credit advanced algebra course	−0.003
	(0.008)
Student enrolls in dual-credit advanced algebra course	−0.021
	(0.058)
Outcome mean for control group	0.92
12th Grade Students (N = 23,091)	
School offers at least one section of dual-credit advanced algebra course	0.001
	(0.007)
Student enrolls in dual-credit advanced algebra course	0.004
	(0.047)
Outcome mean for control group	0.94

Notes: Estimates in this table come from a two-stage, instrumental variables (IV) approach where a school's original randomized assignment to treatment is used as the instrument in the first stage to predict an endogenous variable of interest (e.g., school offered at least one section of dual-credit advanced algebra). All models include baseline demographic and achievement controls described in the text as well as region-by-cohort fixed effects. Robust standard errors clustered at the school level appear in parentheses. Data on high school graduation come from "audited cohort files" maintained by the Tennessee Department of Education. *** $p<0.01$; ** $p<0.05$; * $p<0.1$.

Table A3. Dual-credit advanced algebra, college enrollment, and college choice.

Treatment and Outcome	All Students (1)	Subgroup: Middle 50% Baseline Achievement Distribution (2)	Top 25% Baseline Achievement Distribution (3)	First exposed in 11th Grade (4)	First exposed in 12th Grade (5)	White, Non-Hispanic (6)	Black and Hispanic (7)
Treatment = Student enrolls in dual-credit advanced algebra course							
Enroll in 4-year institution (NSC + THEC)	0.150* (0.086)	0.197** (0.090)	0.071 (0.088)	0.164** (0.080)	0.133 (0.111)	0.153 (0.095)	0.161 (0.098)
Outcome mean for control group	0.33	0.25	0.61	0.33	0.33	0.33	0.30
Enroll in 2-year institution (NSC + THEC)	−0.192** (0.083)	−0.187** (0.086)	−0.102 (0.074)	−0.236*** (0.078)	−0.126 (0.107)	−0.191** (0.090)	−0.166* (0.089)
Outcome mean for control group	0.27	0.32	0.23	0.31	0.24	0.29	0.23
Enroll in any college (NSC + THEC)	−0.031 (0.068)	0.009 (0.087)	−0.006 (0.040)	−0.065 (0.063)	0.019 (0.095)	−0.031 (0.077)	0.011 (0.083)
Outcome mean for control group	0.61	0.58	0.84	0.65	0.58	0.63	0.54
Enroll in TBR-covered institution (THEC)	−0.111 (0.093)	0.003 (0.086)	−0.110 (0.101)	−0.163* (0.091)	−0.029 (0.108)	−0.111 (0.106)	−0.039 (0.091)
Outcome mean for control group	0.36	0.38	0.39	0.39	0.33	0.36	0.35
N(students)	43,839	24,790	13,242	20,998	22,841	35,168	7,502

Notes: Sample includes students whose expected, on-time graduation year (as a function of their audited ninth grade cohort year) is 2013/2014 or 2014/2015 and who were in eleventh or twelfth grade when first exposed to the opportunity to take the dual-credit math course. Postsecondary outcomes are measured within one year of expected, on-time high school graduation; and outcomes that capture choice refer to the first institution in which a student enrolls during that period. Estimates in this table come from a two-stage, instrumental variables (IV) approach where a school's original randomized assignment to treatment is used as the instrument in the first stage to predict an endogenous variable of interest (e.g., student enrolled in dual-credit advanced algebra). All models include baseline demographic and achievement controls described in the text as well as region-by-cohort fixed effects. Robust standard errors clustered at the school level appear in parentheses. *** $p<0.01$; ** $p<0.05$; * $p<0.1$; NSC = National Student Clearinghouse; THEC = Tennessee Higher Education Commission; TBR = Tennessee Board of Regents.

Table A4. Dual-credit advanced algebra and early college success.

Outcome Domain, Treatment, Outcomes	All Students (1)	Subgroup: Middle 50% Baseline Achievement Distribution (2)	Top 25% Baseline Achievement Distribution (3)	First exposed in 11th Grade (4)	First exposed in 12th Grade (5)	White, Non-Hispanic (6)	Black and Hispanic (7)
A. Credit Accumulation							
Treatment = Student enrolls in dual-credit advanced algebra course							
Number of credits earned within year following expected, on-time HS graduation (THEC)	1.385 (2.309)	0.511 (2.475)	3.767 (2.721)	1.294 (2.361)	1.737 (2.828)	1.949 (2.512)	0.230 (3.004)
Outcome mean for control group	22.4	19.2	29.3	22.5	22.3	23.2	18.1
Earn 30 or more credits within year following expected, on-time HS graduation (THEC)	0.036 (0.069)	0.024 (0.074)	0.075 (0.083)	0.040 (0.063)	0.036 (0.096)	0.054 (0.078)	0.011 (0.087)
Outcome mean for control group	0.34	0.22	0.56	0.34	0.33	0.36	0.19
B. Performance in College Math Courses							
Treatment = Student enrolls in dual-credit advanced algebra course							
Enroll in at least one math course within year following expected, on-time HS graduation (TBR)	0.008 (0.075)	−0.007 (0.082)	0.022 (0.078)	0.010 (0.079)	0.024 (0.090)	0.002 (0.077)	0.073 (0.148)
Outcome mean for control group	0.69	0.70	0.68	0.66	0.72	0.68	0.71
Pass at least one math course within year following expected, on-time HS graduation (TBR)	0.041 (0.068)	0.035 (0.075)	0.033 (0.087)	0.007 (0.067)	0.099 (0.087)	0.036 (0.071)	0.098 (0.116)

Table A4. Continued.

		Subgroup					
Outcome Domain, Treatment, Outcomes	All Students (1)	Middle 50% Baseline Achievement Distribution (2)	Top 25% Baseline Achievement Distribution (3)	First exposed in 11th Grade (4)	First exposed in 12th Grade (5)	White, Non-Hispanic (6)	Black and Hispanic (7)
Outcome mean for control group	0.50	0.49	0.57	0.48	0.52	0.51	0.46
Withdraw from at least one math course within year following expected, on-time HS graduation (TBR)	−0.041 (0.028)	−0.069* (0.036)	0.004 (0.023)	−0.024 (0.027)	−0.065 (0.045)	−0.049* (0.028)	0.016 (0.063)
Outcome mean for control group	0.06	0.07	0.05	0.07	0.06	0.06	0.07
N(students) - THEC sample	20,069	11,222	7,540	10,322	9,747	16,425	3,060
N(students) - TBR sample	15,259	9,362	4,837	7,855	7,404	12,236	2,614

Notes: The analytic sample for outcomes in panel A includes students whose expected, on-time graduation year (as a function of their audited ninth grade cohort year) is 2013/2014 or 2014/2015, were in eleventh or twelfth grade when first exposed to the opportunity to take the dual-credit math course, and attended a Tennessee public institution of any kind within one year of expected, on-time high school graduation. Measures of cumulative credits include courses taken during summer terms. The analytic sample for outcomes in panel B is the subset of students in the analytic sample for panel A who enroll in a two-year or four-year public institution covered by TBR in the year following expected, on-time high school graduation. Course-based outcomes include information from courses taken in summer terms. Estimates in this table come from a two-stage, instrumental variables (IV) approach where a school's original randomized assignment to treatment is used as the instrument in the first stage to predict an endogenous variable of interest (e.g., student enrolled in dual-credit advanced algebra). All models include baseline demographic and achievement controls described in the text as well as region-by-cohort fixed effects. Robust standard errors clustered at the school level appear in parentheses. *** p<0.01; ** p<0.05; * p<0.1; THEC = Tennessee Higher Education Commission; TBR = Tennessee Board of Regents.

Table A5. Teacher characteristics and survey response.

Independent variable	Responded to Survey (1)
Treatment teacher (cohort 2)	0.204***
	(0.077)
White	−0.084
	(0.237)
Male	−0.063
	(0.084)
Number of years of teaching experience	0.005
	(0.005)
Age (as of Sept 1, 2014)	−0.004
	(0.005)
Highest degree - Master's or Master's Plus	−0.101
	(0.092)
Highest degree - EDS or PhD	−0.232
	(0.149)
Teacher is missing any demographic info	−0.115
	(0.300)
Sample	All AAT teachers in treatment and control schools in 2013/2014
Region fixed effects	Y
N(teachers)	117
R-squared	0.10

Notes: See text for description of sample creation for teacher survey. Robust standard errors are in parentheses. *** $p<0.01$; ** $p<0.05$; * $p<0.1$; the reference category for the pair of "highest degree" variables is "Bachelor's."

APPENDIX B

TENNESSEE DEPARTMENT OF EDUCATION
FIRST TO THE TOP

Statewide Dual Credit for College Algebra (MATH 1130)
(Advanced Algebra and Trigonometry #3124)

LEARNING OBJECTIVES

Dual Credit College Algebra Competencies

Numeric and Algebraic Operations (23%)
Describe Equations (5%)
Solve Equations (23%)
Solve Inequalities (10%)
Function and their Properties (32%)
Representation/modeling (7%)

I. Numeric and Algebraic Operations (23%)

1) Factoring and Expanding Polynomials
   - Factor quadratics completely
   - Factor polynomials completely (degree ≤ 5)
   - Determine a binomial expansion
2) Operations with Numbers
   - Complex Numbers: Perform basic operations (add, subtract, multiply, divide, conjugate)
3) Operations with algebraic expressions
   - Perform basic operations (+, - ×, ÷) with rational expressions
   - Simplify complex rational expressions
4) Operations with exponents
   - Apply the properties of exponents (including rational exponents)
5) Operations with logarithms
   - Apply the properties of logarithms

II. Describe Equations (5%)

1) Write an equation of a line (parallel, perpendicular, point/slope, two points)
2) Write an equation of a parabola given vertex and one point.

III. Solve Equations* (23%)

1) Solve linear equations.
2) Solve application problems involving linear equations (mixture, motion, simple interest, constant rate job)
3) Graph linear equations in the Cartesian coordinate system.
4) Solve systems of linear equations (two equations with two unknowns)
5) Solve quadratic equations that have both real and complex solutions (factoring, quadratic formula, square root method)
6) Graph quadratic equations in the Cartesian coordinate system.
7) Solve absolute value equations (linear)
8) Solve rational equations
9) Solve radical equations involving a single square root

10) Solve exponential equations
11) Solve logarithmic equations

*One variable unless in Cartesian coordinate system

IV. Solve Inequalities* (10%)

1) Solve linear inequalities
2) Solve application problems involving linear inequalities
3) Solve quadratic inequalities
4) Solve absolute value inequalities
5) Graph linear inequalities in the Cartesian coordinate system.
6) Graph systems of linear inequalities in the Cartesian coordinate system (2 inequalities with 2 unknowns)

* One variable unless in Cartesian coordinate system

V. Function and Their Properties (32%)**

1) Definitions (Each test may contain a variety of functions including linear, polynomial (degree ≤ 5), rational, absolute value, power, exponential, logarithmic and piecewise- defined)
   - Determine whether a relation is a function from its graph.
   - Evaluate functions for given values.
   - Determine type of functions (linear, quadratic, polynomial greater than 2nd degree, rational, exponential, logarithmic, radical, absolute value, piece-wise)
   - Determine domain of a function from equation or graph.
   - Determine range of a function from a graph.
2) Graphs and Their Properties (Graphing includes sketch of the graph showing intercepts, symmetry and other important characteristics)
   - Graph polynomial functions of degree greater than 2.
   - Graph exponential functions.
   - Graph logarithmic functions.
   - Graph rational functions (asymptotes – horizontal and vertical)
   - Graph radical functions
   - Identify intervals on which functions are increasing, decreasing and constant (from a graph)
   - Identify and apply transformations to a graph (horizontal, vertical, reflections, stretching/shrinking)
3) Algebra of Functions and Inverse functions
   - Perform basic function operations (add, subtract, multiply, divide)
   - Evaluate composition of functions
   - Simplify composite functions
   - Determine if a given function has an inverse function
   - Find the inverse function of a given function if it exists

VI. Representation/modeling (graphical, numerical, symbolic and verbal) (7%)

1) Solve real world problems involving variation, using both direct and inverse proportionality.
2) Solve real world problems involving exponential functions (compound interest, exponential growth and decay).
3) Solve real world problems involving logarithms (radioactive decay, decibels, or the Richter scale).

APPENDIX C

Advanced Algebra and Trigonometry (AAT)
Dual Credit Class Teacher Survey

Previously, we wrote to you about the statewide evaluation of the dual-credit policy in Tennessee and asked for your future participation in a brief survey about your Advanced Algebra and Trigonometry (AAT) class. We initially asked for your participation in an online survey and are following up with you with a paper version of the survey.

This brief 5 – 10 minute survey will help us to understand the course learning objectives, as well as your experience teaching the course. Your participation is voluntary and will not be reported to your school. Your responses will remain confidential, used for the purpose of this evaluation, and will only be reported in the aggregate.

When you have completed the survey, please use the enclosed envelope (NO POSTAGE IS NECESSARY) to mail the survey back to us.

Please check one:
❍ I have read the information above and I agree to participate in this research study.
❍ I do not agree to participate in this research study.

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1. Which semester(s) did you teach the Advanced Algebra and Trigonometry (AAT) course?
❍ Fall 2014 only
❍ Spring 2015 only
❍ Fall 2014 & Spring 2015
❍ I did not teach AAT for the 2014-15 school year

I. CURRICULUM

2. Please answer the following about the textbook that you used for your AAT class: (If you used more than one textbook, please select the textbook that your students used most often.)

Title: ______________________________

Author: ______________________________

Year: ______________________________

Publisher: ______________________________

3. For the following questions, please refer to your weekly curriculum plan or syllabus when responding.

<u>In the THIRD FULL WEEK of class...</u>

a. Which mathematical concept(s) did you cover? (i.e. prime numbers, matrices, primitive roots, factoring polynomials, etc.)

b. Which chapter(s) of the textbook did you teach?

Advanced Algebra and Trigonometry (AAT)
Dual Credit Class Teacher Survey

c. Which of the following did you assign to your students (select ALL that apply):
- ❑ Readings from the textbook
- ❑ Individual problem set
- ❑ Group problem set
- ❑ Practice exam
- ❑ Other (please specify): ____________________
- ❑ No assignments

4. For the following questions, please refer to your weekly curriculum plan or syllabus when responding.

<u>TWO WEEKS BEFORE THE MIDTERM ...</u>

a. Which mathematical concept(s) did you cover? (i.e. prime numbers, matrices, primitive roots, factoring polynomials, etc.)

b. Which chapter(s) of the textbook did you teach?

c. Which of the following did you assign to your students (select ALL that apply):
- ❑ Readings from the textbook
- ❑ Individual problem set
- ❑ Group problem set
- ❑ Practice exam
- ❑ Other (please specify): ____________________
- ❑ No assignments

5. For the following questions, please refer to your weekly curriculum plan or syllabus when responding.

<u>TWO WEEKS BEFORE THE FINAL EXAM ...</u>

a. Which mathematical concept(s) did you cover? (i.e. prime numbers, matrices, primitive roots, factoring polynomials, etc.)

b. Which chapter(s) of the textbook did you teach?

c. Which of the following did you assign to your students (select ALL that apply):
- ❑ Readings from the textbook
- ❑ Individual problem set
- ❑ Group problem set
- ❑ Practice exam
- ❑ Other (please specify): ____________________
- ❑ No assignments

6a. Please think about the state standards for the dual credit AAT class. Which standard(s) did you emphasize in your class?

Advanced Algebra and Trigonometry (AAT)
Dual Credit Class Teacher Survey

6b. Please think about the state standards for the dual credit AAT class. With which standard(s) did your students have the most trouble?

II. AAT Challenge Exam

7. Please think about your students before they enrolled in your AAT course. Prior to your class, had more than half of your students taken an online assessment?

- ❍ Yes
- ❍ No
- ❍ Uncertain

8a. How satisfied were you with the alignment of the practice tests to the AAT challenge exam?

- ❍ Satisfied
- ❍ Somewhat Satisfied
- ❍ Neutral
- ❍ Somewhat Dissatisfied
- ❍ Dissatisfied

8b. Please explain:

9. Please describe your school's experience with administering the AAT challenge exam:

III. Previous Experience with the AAT Class

10a. Did you teach a dual credit AAT class in the 2013 - 14 school year?

- ❍ Yes
- ❍ No ⟶ Skip to IV. Collection of Classroom Materials

10b. Comparing the 2013-14 class to your 2014-15 class, did you change any of the following during this school year (select ALL that apply):

- ❑ Order of teaching of the mathematical concepts
- ❑ Spent more time on certain mathematical concepts (please specify): ______________________________
- ❑ Textbook
- ❑ Increased the number of problem sets assigned
- ❑ Increased the number of problems on the homework
- ❑ Increased the number of practice tests assigned
- ❑ Other (please specify): ______________________________
- ❑ There were no changes

Advanced Algebra and Trigonometry (AAT)
Dual Credit Class Teacher Survey

IV. Collection of Classroom Material

We are striving to better understand the classroom experience of the dual credit AAT course and are seeking to collect classroom material such as syllabi, homework, midterms, and/or final exams. This material will allow us to make more in-depth and useful recommendations to future AAT teachers.

If you are willing to share your classroom material, please either enclose copies of these documents with your completed survey –or– email electronic versions of these documents to Meredith Billings at msbill@umich.edu.

Thank you for your participation in this survey!

If you have questions about your rights as a research participant, please contact the University of Michigan Institutional Review Board Health Sciences and Behavioral Sciences, 2800 Plymouth Rd., Building 520, Room 1169, Ann Arbor, MI 48109-2800 at (734) 936-0933 [or toll free, (866) 936-0933] or irbhsbs@umich.edu.

Previously, we wrote to you about the statewide evaluation of the dual-credit policy in Tennessee and asked for your future participation in a brief survey about your Advanced Algebra and Trigonometry (AAT) class. We initially asked for your participation in an online survey and are following up with you with a paper version of the survey.

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1. Which semester(s) did you teach the Advanced Algebra and Trigonometry (AAT) course?
❍ Fall 2014 only
❍ Spring 2015 only
❍ Fall 2014 & Spring 2015
❍ I did not teach AAT for the 2014-15 school year

I. CURRICULUM

2. Please answer the following about the textbook that you used for your AAT class: (If you used more than one textbook, please select the textbook that your students used most often.)

Advanced Algebra and Trigonometry (AAT) Class Teacher Survey

Title: ____

Author: ____

Year: ____

Publisher: ____

3. For the following questions, please refer to your weekly curriculum plan or syllabus when responding.

In the THIRD FULL WEEK of class...

a. Which mathematical concept(s) did you cover? (i.e. prime numbers, matrices, primitive roots, factoring polynomials, etc.)

b. Which chapter(s) of the textbook did you teach?

c. Which of the following did you assign to your students (select ALL that apply):
- ❑ Readings from the textbook
- ❑ Individual problem set
- ❑ Group problem set
- ❑ Practice exam
- ❑ Other (please specify): ____________________
- ❑ No assignments

4. For the following questions, please refer to your weekly curriculum plan or syllabus when responding.

TWO WEEKS BEFORE THE MIDTERM ...

a. Which mathematical concept(s) did you cover? (i.e. prime numbers, matrices, primitive roots, factoring polynomials, etc.)

b. Which chapter(s) of the textbook did you teach?

c. Which of the following did you assign to your students (select ALL that apply):
- ❑ Readings from the textbook
- ❑ Individual problem set
- ❑ Group problem set
- ❑ Practice exam
- ❑ Other (please specify): ____________________
- ❑ No assignments

5. For the following questions, please refer to your weekly curriculum plan or syllabus when responding.

Advanced Algebra and Trigonometry (AAT) Class Teacher Survey

TWO WEEKS BEFORE THE FINAL EXAM ...

a. Which mathematical concept(s) did you cover? (i.e. prime numbers, matrices, primitive roots, factoring polynomials, etc.)

b. Which chapter(s) of the textbook did you teach?

c. Which of the following did you assign to your students (select ALL that apply):
- ❑ Readings from the textbook
- ❑ Individual problem set
- ❑ Group problem set
- ❑ Practice exam
- ❑ Other (please specify): ____________________
- ❑ No assignments

6. Please think about the state standards for your AAT class. With which standard(s) did your students have the most trouble?

II. Online Assessment

7. Please think about your students before they enrolled in your AAT course. Prior to your class, had more than half of your students taken an online assessment?
- ❍ Yes
- ❍ No
- ❍ Uncertain

8. Does your school have the resources (i.e. room, computers, proctor, etc.) to conduct online testing for a class about the size of your AAT class?
- ❍ Yes
- ❍ No
- ❍ Uncertain

III. Previous Experience with the AAT Class

9a. Did you teach an AAT class in the 2013 - 14 school year?
- ❍ Yes
- ❍ No ⟶ Skip to IV. Collection of Classroom Materials

9b. Comparing the 2013-14 class to your 2014-15 class, did you change any of the following during this school year (select ALL that apply):
- ❑ Order of teaching of the mathematical concepts
- ❑ Spent more time on certain mathematical concepts (please specify):

  ____

- ❑ Textbook
- ❑ Increased the number of problem sets assigned
- ❑ Increased the number of problems on the homework

Advanced Algebra and Trigonometry (AAT) Class Teacher Survey

- ❑ Increased the number of practice tests assigned
- ❑ Other (please specify): ______________________________
- ❑ There were no changes

IV. Collection of Classroom Material

We are striving to better understand the classroom experience of the AAT course and are seeking to collect classroom material such as syllabi, homework, midterms, and/or final exams. This material will allow us to make more in-depth and useful recommendations to future AAT teachers.

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