Abstract Title Page

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Title: The Role of Applied Engineering and Computer Science Courses in the Production of Math Achievement in High School

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Abstract Body

Background / Context: The importance of a well-trained scientific workforce to the nation's economic vitality cannot be overstated. We rely on scientists and engineers to ensure our national security, to solve our most critical problems, and to increase our general standard of living (Hira, 2010). Despite the essential role these specialized workers play, policy makers, educators, and business leaders are deeply concerned about the quantity and quality of American youth in line to adopt these positions. In terms of quantity, the percentage of undergraduates pursuing degrees in engineering, physical science, and math have remained stagnant, and the percentage pursuing computer science has declined (National Science Board, 2010). In terms of quality, American youth are ill-prepared relative to their international counterparts. For example, 15 year-olds in the United States rank 16 out of 26 countries in science literacy and 19 out of 26 countries in mathematics literacy (National Science Board, 2010). These statistics do not bode well for a young workforce entering a highly competitive and global economy.

Due to these concerns regarding quantity and quality, there has been an increased pressure on the education system to take a more proactive approach in preparing youth for careers in STEM fields. In response, a number of federal policy initiatives have been enacted with specific provisions for the enhancement of the STEM curriculum in schools. For example, the Carl D. Perkins Career and Technical Education Improvement Act of 2006 provides funds for the development of STEM curricula for both college and non-college bound youth, and the America COMPETES Act of 2007 supports programs that increase the number of teachers qualified to teach STEM in high school. Despite this push at the federal level, education in the United States is largely designed and administered at the local level, and consequently, the adoption and adaptation of STEM support mechanisms varies considerably across schools, districts, and states.

In general, there are two types of STEM courses: *academic* and *applied*. Academic STEM courses include math and science courses that comprise the traditional academic curriculum. These include courses such as algebra, geometry, calculus, biology, chemistry, and physics. Academic courses are typically taught from a theoretical approach that stresses observation, identification, documentation, and computation. Concepts are taught in the context of the classroom, where knowledge is largely for knowledge sake, or at the very least, for an exam.

Applied STEM courses, on the other hand, stress the application of academic concepts to "real world" job experiences while incorporating quantitative skills, logic, and problem solving. By design, applied courses impart skills and knowledge that have direct "currency" to the daily challenges and problems students will face should they pursue a STEM career. There are two main strands of applied STEM in the high school curriculum: computer/information sciences courses and engineering technologies courses.[2] Computer/information sciences include courses such as introduction to computer science, C++ programming, visual basic programming, and data processing. Engineering technologies courses include surveying, electrical engineering, structural engineering, and computer-assisted design/drafting. Nationally, among the class of 2005, 19 percent of students had earned course credit in computer/information science and 12 percent had earned course credit in engineering technologies (Hudson & Laird, 2009).

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[2] For ease of expression, we use the expression "applied STEM courses" to refer to both computer/information science courses and engineering technologies courses throughout.

While a large number of studies demonstrate that *academic* STEM courses are associated with gains in learning (Bozick & Ingels, 2008) as well as favorable postsecondary education outcomes (Tyson, Lee, Borman, & Hanson, 2007), and favorable labor market outcomes (Gamoran, 1998), it is unknown whether the same holds true for *applied* STEM courses. Some research on occupational coursetaking more broadly – of which applied STEM is only one component – finds that these courses in the aggregate (which also include business, manufacturing, etc.) have little bearing on learning (Agodini, 2001; Rasinski & Pedlow, 1998), but may improve employment prospects (Ainsworth & Roscigno, 2005; Bishop & Mane, 2004). However, to our knowledge, there is no research that explicitly examines engineering technologies and computer/information science courses apart from the range of occupational courses in student curriculum. Therefore, our research will produce new knowledge on the efficacy of applied STEM courses in the larger context of math and science coursetaking.

Purpose / Objective / Research Question / Focus of Study: Academic math and science courses have been long shown to increase learning and educational attainment (Bozick & Ingels 2008; Tyson et al., 2007), but are they sufficient on their own to prepare youth for the challenges and rigor of the STEM workforce? Or, are there distinctive benefits to complementing these traditional academic courses with applied ones? Answers to these questions are particularly critical as schools try to balance the competing demands of providing youth with the applied skills and knowledge to thrive in the adult labor force while at the same time ensuring they are meeting high standards of academic competency that are required for college. With respect to the latter, the emphasis on standardized testing has exacerbated these concerns, and in some cases, test preparation and an over emphasis on academic subjects has "crowded out" other components of the curriculum (Nichols & Berliner, 2007). With these competing demands and faced with limited resources, education policy makers must make informed choices regarding how to best structure their curriculum to meet the needs of a diverse student population. To this end, our proposed project will address three research questions:

1. What applied STEM courses are most commonly taken by high school students?

2. To what extent are high school students taking both academic and applied STEM courses?

3. Do applied STEM courses in high school improve achievement in math?

Setting: Public and Private Secondary Schools in the United States

Population / Participants / Subjects: For this project, we propose to analyze the Education Longitudinal Study of 2002 (ELS:2002), a nationally representative study of 10th-graders in 2002 sponsored by the National Center for Education Statistics (NCES). ELS:2002 was collected via a two-stage sampling procedure. In the first stage, a sample of 750 high schools, both public and private, were selected with probabilities proportional to their size. In the second stage, approximately 30 students were randomly sampled from each school on the condition that they were in the 10th grade in the spring term of the 2001-02 school year, yielding a sample of approximately 15,360 students. These 10th graders were interviewed about their school and home experiences and they were administered a mathematics assessment. Sample members were re-interviewed in the spring of 2004 when most were seniors, and again in the spring of 2006, when most were two years out of high school.[3] Additionally, their high school transcripts were collected. For this paper, we will analyze the 14,290 sample members who have full transcript information – a necessary condition for us to assess coursetaking in high school.

Intervention / Program / Practice: The key "intervention" studied in this paper is *academic* STEM courses and *applied* STEM courses taken during high school. Academic courses include math and science and applied courses include computer/information sciences and engineering technologies. These classifications are taken from the Secondary School Taxonomy, which organizes all high school courses recorded on students' transcripts into four distinct curricula: academic, career and technical education (CTE), enrichment/other, and special education. Math and science are "traditional" subjects that – along with English, social studies, fine arts, and non-English language – comprise the academic curriculum. Computer/information sciences and engineering technologies, on the other hand, have a distinct occupational focus and are part of the CTE curriculum. This taxonomy is mutually exclusive such that courses classified as academic are not also classified as CTE and vice versa.

Research Design: Our analysis will be comprised of two parts: a descriptive overview of the STEM coursetaking landscape in high school (to answer research questions 1 & 2) and an econometric test of the efficacy of applied math and science coursetaking in promoting advancement toward STEM careers (to answer research question 3). The descriptive overview will document the types of math and science courses that students take, when in high school they take them, and in what combination. See Tables 1 and 2 in the appendices as examples of the format of our descriptive overview. (please insert tables 1 and 2 here)

To address question 3, we will apply multivariate, quasi-experimental techniques to discern whether academic courses, applied courses, or combinations of the two support math learning. We operationalize math learning using scores on a standardized math assessment, administered in both the base-year (10^{th} grade) and first follow-up (12^{th} grade) surveys. These assessments were designed to maximize the accuracy of measurement that could be achieved in a limited amount of testing time while minimizing floor and ceiling effects, by matching sets of test questions to initial estimates of students' achievement. For this analysis, six measures of mathematics achievement based on performance on this test are used: a number-right score and five proficiency probability scores. The number-right score is an overall measure of mathematical knowledge and indicates the number of items answered correctly. A proficiency probability score is a criterion-referenced score indicating mastery of specific skills and knowledge. Using these scores as outcomes, we will estimate the following model:

$$Y_{ikst} = \beta_0 + \beta_1 APL_{it} + \beta_2 ACA_{it} + \beta_3 I_{it} + \beta_4 F_{it} + \beta_5 S_t + \beta_6 R_t + \beta_7 Y_{ik(t-1)} + \gamma_{ikst}$$

where Y is standardized math performance for student i in school k in state s at time t as the dependent variable on the left-hand side of the equation and at time $t-1$ as the lagged measure of achievement on the right-hand side of the equation. Empirically, the sets of independent

[3] Sample members were followed regardless of whether they changed schools, dropped out, or were held back a grade.

variables, described by the education production function, would be estimated as follows. At this student level, APL is a binary indicator, designating whether a student has taken applied coursework. To account for the extent of academic coursework a student has taken, ACA is a vector of binary variables indicating the highest level of mathematics course taken. Other sets of student-level variables include: I, a vector of a student's characteristics and F family characteristics. At the school level, the model assigns the following inputs: S are school-specific characteristics and R are regional indicators. Finally, the error term γ includes all unobserved determinants of achievement. It is also in this error term that state fixed effects are identified: they control for the common influences of states by capturing differences across each state.

To account for unobserved heterogeneity at the school level, we employ school fixed effects as a second model in our analyses. A reason for school fixed effects arises because there are potential unobserved school factors that may be influencing both student selection of coursework as well as testing performance. For instance, it might be hypothesized that being part of an academically-involved school environment might simultaneously be correlated with selection of academic over applied coursework as well as math test performance. Thus, this unobserved school environment may cause an overestimation of the effect of academic STEM coursework and underestimate the effect of applied coursework.

Data Collection and Analysis: This project makes use of data that have already been collected by NCES. In all of our analyses that require tests of significance, we will adjust our standard errors using Taylor-series linearization methods to account for the clustered and stratified sampling design of ELS:2002. We will also use probability weights to adjust our estimates for sampling and item non-response. Also, we will examine the extent of missing data on critical items in our analysis, and explore imputation options should missing data threaten to bias our estimates.

Findings / Results: This analysis will be supported by a National Science Foundation grant that was recently awarded to the authors. The full paper, with results, will be ready in time for the SREE 2012 conference.

Conclusions: Our study will help contribute to our knowledge of the STEM curriculum in high school in two distinct ways. First, this study will be the first to explore applied STEM courses taken by students. Currently, there are no national estimates on the types, timing, and prevalence of applied STEM courses taken by U.S. students. Second, this study will be the first to jointly evaluate the efficacy of both academic and applied STEM courses. Although a number of national studies have examined the importance of math and science courses for academic outcomes, none have looked at whether applied STEM courses yield the same results and none have looked at how taking both academic and applied STEM courses support advancement toward STEM careers. This is particularly important as students are increasingly taking both types of courses. When full results are available, our conclusions will further explicate how these two contributions contribute to a broader policy discussion on the structure of the high school curriculum in a changing economic environment.

Appendices

Appendix A. References

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Appendix B. Tables and Figures

Table 1. Percentage Earnings Credits in Engineering Technologies Courses

		Percent Among Credit Earners			
	Percent earning credits	Earned Credit in 9th Grade	Earned Credit in 10th Grade	Earned Credit in 11th Grade	Earned Credit in 12th Grade
Engineering Technologies (all)					
Surveying					
Electrical Engineering					
Computer Assisted Design/Drafting					
Course title					
Course title					
etc.					

Table 2. Percentage Earnings Credits in Engineering Technologies Courses for Each Level of the Math Pipeline

	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
Engineering Technologies (all)								
Surveying								
Electrical Engineering								
Computer Assisted Design/Drafting								
Course title								
Course title								
etc.								