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Abstract

This study used hierarchical linear regression to examine the effects of taking specific high school courses on students' ACT performance in English, Mathematics, and Science. In addition, hierarchical logistic regression was used to examine the benefits of taking specific courses on students' likelihood of meeting or exceeding the ACT College Readiness Benchmarks in these three subject areas. All effects were examined in the context of the high schools students attended. Moreover, school characteristics were examined to determine whether course work effects were differentially influenced by the characteristics of the schools students attended.

The data for the study consisted of 403,381 students from 10,792 high schools who took PLAN as sophomores and the ACT as juniors or seniors. Patterns of course work taken were developed from the Course Grade Information Section of the ACT.

The results supported the use of hierarchical modeling for examining the contribution of course work taken to ACT performance. The relationships between course work taken and ACT performance were influenced by the characteristics of schools, most often the accrediting region of the school.

Using Hierarchical Modeling to Examine Course Work and ACT Score Relationships Across High Schools[1]

Hierarchical regression modeling is becoming increasingly popular as a methodology for analyzing data in the social sciences. It is used in situations where data are nested within groups, when the outcome variable of interest may depend on both individual characteristics and group membership. For example, students differ in the high school courses they take and their overall achievement, but there are also differences across schools in the types of courses they offer and their grading standards in those courses. Failing to account for both sources of variability in a regression model can result in incorrect conclusions about predictor-outcome relationships (Snidjers & Bosker, 1999).

Basic Structure of Hierarchical Modeling

Hierarchical models are extensions of regression models, such as basic linear and logistic regression models. For example, a researcher is interested in predicting high school GPA at graduation from students' gender and the number of years of mathematics course work taken in high school. High school GPA and the predictors are student-level variables. A basic linear regression model is appropriate, as in:

$$Y_i = B_0 + B_1X_{i1} + B_2X_{i2} + R_i$$

where high school GPA (Y_i) is predicted from gender (X_{i1}) and mathematics course work (X_{i2}). The weights B_0, B_1, and B_2 are regression coefficients; R_i is the error term and is assumed to be independent across students. However, the effects of course work and gender on high school GPA may depend on the high school students attend.

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[1] Results from this research are also summarized in the ACT Policy Report *Courses Count: Preparing Students for Postsecondary Success*, 2005.

Hierarchical modeling allows researchers to address issues of this type by partitioning variability across, as in this example, students and schools. It simultaneously fits two sets of regression equations: one at level 1 (the student level) and a second set at level 2 (the school level). Researchers can then investigate the extent to which, for example, class size might influence the relationship across schools between mathematics course work and high school GPA.

The level 1 regression equation is analogous to the standard multiple linear regression equation shown above, but where Y is the outcome variable (high school GPA) for students within schools and the regression coefficients (β) are specific to each school j:

$$Y_{ij} = \beta_{0j} + \beta_{1j}x_{1ij} + \beta_{2j}x_{2ij} + R_{ij}$$

The level 2, or school-level, models consist of regression equations for each of the level 1 regression coefficients, as in

$$\beta_{0j} = \gamma_{00} + \gamma_{01}\, z_j + U_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}\, z_j + U_{1j}$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}\, z_j + U_{2j}$$

where z represents a group-level covariate, such as class size, γ_{00} represents the average group mean (i.e., intercept) across groups when $z = 0$, γ_{10} and γ_{20} represent the average slopes for level 1 variables x_1 and x_2 across groups when $z = 0$, and γ_{01}, γ_{11}, and γ_{21} represent the mean differences in intercepts and slopes associated with z. A group-level covariate may also be centered around its mean, in which case the interpretations of level 2 slopes and intercepts are not restricted to the condition that $z = 0$.

In most hierarchical models, the level 2 equations include random effects that are associated with different groups (U_j). Random level 2 effects reflect the fact that the level 2 models are an approximation. For groups with small sample sizes, including random effects avoids overfitting of the model and obtaining large standard errors. Moreover, random level 2 effects enable researchers to test for the effects of group-level predictors, as in the example, where class size was used to predict the level 1 coefficients. In addition, random effects allow researchers to generalize their findings to the broader population of groups, rather than only applying their conclusions to the groups included in the study. For a complete discussion of hierarchical modeling, see Raudenbush and Bryk (2002) or Snidjers and Bosker (1999).

ACT Research on Course Work and Achievement

ACT research has shown that taking rigorous, college preparatory mathematics courses is associated with higher ACT Mathematics and Composite scores. (e.g., ACT, 2004; Noble, Davenport, and Sawyer, 2001; Noble, Roberts, and Sawyer, 2006). Schiel, Pommerich, and Noble (1996) statistically controlled for prior achievement using PLAN scores, and found substantive increases in average ACT Mathematics and Science scores associated with taking upper-level mathematics and science courses.

The majority of research over the past 10 years on ACT scores and high school course work has statistically controlled for high school attended (e.g., Noble, Roberts, and Sawyer, 2006; Schiel, Pommerich, and Noble, 1996). In some studies, effect-coded dummy variables were used to represent high school attended in traditional multiple linear regression models (e.g., Noble, Davenport, Schiel, and Pommerich, 1999). In other studies (e.g, Schiel, Pommerich, and Noble, 1996), within-high school regression models were developed and then the distributions of regression coefficients were summarized across schools using median, minimum, and maximum values. In all cases, high school attended had a significant effect on the contribution of course work taken, either through reducing the amount of unexplained variance in the criterion variable or illustrating the variability of the course work regression coefficients across high schools.

In effect-coded dummy variable models, as in the Noble et al. (1999) study, each dummy variable represents the difference between a given high school's performance and the average performance of all high schools on the criterion variable (i.e., an adjustment to the intercept term). Unless dummy variable by course work interaction terms are included in the model, the course work regression coefficients are forced to be equal across high schools. With a large number of schools, such interaction terms become very complex and the model difficult to interpret. Moreover, regardless of the interaction terms, using dummy variables can result in inflated R^2 values, due to the number of variables in the model; an increased Type 1 error rate when evaluating school-level differences; and an increased Type 2 error rate when evaluating the effects of student-level differences within schools (Snidjers and Bosker, 1999). In comparison, hierarchical models can include school-level intercept and slope adjustments for all regression coefficients in the model, and minimize R^2 inflation and Type 1 and Type 2 error rates.

Using within-school regression models, as in the Schiel et al. (1996) study, captures variability across high schools in both the slope and intercept terms. However, this approach suffers from two important limitations: First, in order to develop within-school regression models, there must be a sufficient number of students within each school to develop stable results. Very small schools must be ignored, resulting in a possible biasing of the results. Second, though course work variables were allowed to vary across schools, this approach fails to quantify variability in the regression coefficients across schools; only within-school variability is included in the error terms for each regression coefficient. In contrast, hierarchical modeling allows for very small sample sizes and applies the appropriate error terms for school-level and student-level effects.

Given the potential benefits of hierarchical modeling over other methodologies used previously, in this study we used hierarchical regression to examine the effects of taking specific high school courses on student's ACT performance in English, Mathematics, and Science. All effects were examined in the context of the high schools students attended. Moreover, school characteristics were examined to determine whether course work effects were differentially influenced by the characteristics of the schools students attended.

ACT conducted a study in spring 2003 (Allen & Sconing, 2005) to identify ACT scores associated with successful performance in first year college courses. The results identified those scores corresponding to a 50% chance of a B or higher, or at least a 75% chance of a C or higher, in English Composition, College Algebra, and College Biology. These scores included an ACT English score of 18, an ACT Mathematics score of 22, and an ACT Science score of 24. Thus, ACT-tested students who meet or exceed these Benchmarks are likely to be successful in entry-level, credit-bearing college courses. However, to-date no research has been done examining the relationship between high school course work taken and meeting or exceeding these Benchmarks. For this study we therefore examined the effects of taking specific courses on meeting ACT's College Readiness Benchmarks.

Data

The ACT and PLAN tests (ACT, 1997; 1999) are intended to measure high-order thinking skills in four content areas (English, Mathematics, Reading, and Science). Scores range from 1 to 32 for PLAN and 1 to 36 for the ACT. The Composite score is the rounded arithmetic average of the four subject area scores.

In general, students who are high achieving at the time they enter high school take more rigorous, higher-level courses than do students who are lower-achieving. Therefore, it is important to differentiate whether students receive higher ACT scores because of the courses they take or because of their prior achievement. For this study, prior achievement was statistically controlled by including students' PLAN subject area scores in the hierarchical models.

The PLAN/ACT cohort file for the 2003 graduating class contained matched records of students who completed PLAN during their sophomore year (2000-01) and the ACT during their junior or senior year, prior to graduating in 2003[2]. If students took the ACT more than once, only the most recent ACT record was used. Each record included PLAN and ACT scores (in English, Mathematics, and Science), race/ethnicity, grade level at the time of taking the ACT, and self-reported course work information. Three dichotomous variables (1, 0) were also created for each student, representing whether or not s/he met each of the three College Readiness Benchmarks.

Students' grade level at the time of ACT testing was also included in the hierarchical models. The course work students report having taken by the time they complete the ACT depends on their grade level. In addition, the PLAN test is typically taken by high school sophomores; students can take the ACT as juniors and/or as seniors. The time span between PLAN and ACT testing can therefore range from a few months to two or more years.

The Course Grade Information Section (CGIS) of the ACT provides information about students' course work in 30 specific high school courses. Students are asked to indicate whether they have taken or are currently taking a particular course, or whether they plan to take it in the

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[2] Virtually every student in the matched file attended the same high school at the time of ACT testing that he or she had attended at the time of PLAN testing. There were, however, some students who transferred to different schools prior to taking the ACT

future. In earlier studies, students were found to report these data with a high degree of accuracy relative to information provided in their transcripts (Sawyer, Laing and Houston, 1988; Valiga, 1987). Dummy variables were created to make specific course comparisons; the course patterns were based on previous research (ACT, 2004; Noble, Davenport, Schiel, & Pommerich, 1999) and were constructed such that the incremental benefit of specific courses could be determined. The patterns studied included the following:

1. English 9, English 10, and English 11 vs. taking less than these three courses
2. English 9, English 10, and English 11 vs. English 9, English 10, and English 11 and one or more foreign languages
3. Algebra 1, Algebra 2, and Geometry vs. taking less than these three courses
4. Algebra 1, Algebra 2, and Geometry vs. Algebra 1, Algebra 2, Geometry and Other Advanced Mathematics
5. Algebra 1, Algebra 2, and Geometry vs. Algebra 1, Algebra 2, Geometry and Trigonometry
6. Algebra 1, Algebra 2, and Geometry vs. Algebra 1, Algebra 2, Geometry, Trigonometry, and Calculus
7. Algebra 1, Algebra 2, and Geometry vs. Algebra 1, Algebra 2, Geometry, Other Advanced Math, Trigonometry, and Calculus
8. General Science and Biology, or Biology only (denoted as Biology), vs. taking General Science
9. Biology vs. Biology and Chemistry
10. Biology vs. Biology, Chemistry, and Physics

College English instructors rank grammar high in importance as a prerequisite skill for college English Composition (ACT, 2003). Therefore, the ACT English test includes basic grammar and usage in its test specifications. Research shows that taking a foreign language requires some understanding of rules of grammar in order to understand the grammatical system specific to that language (ZhonggangGao, 2001). Taking one or more foreign languages was therefore included as a variable to determine whether it was a viable predictor of ACT English score and the ACT English Benchmark, over and above taking English 9-11.

Characteristics of the schools in the study were obtained from the Market Data Retrieval (MDR) data history and were matched to each student record. These variables were selected based on prior research (e.g., Noble, 2003; Roberts and Noble, 2004; Schiel, Pommerich, and Noble, 1996) and included the following:

1. School type (public or private)
2. Class size (in hundreds)
3. Location (urban, rural, suburban)
4. Accrediting region (South, Northwest, North Central, West, Northeast)
5. School district type (single or multi-school district)

Dummy variables were created for school type, location, and school district type. Location was coded such that rural and suburban schools were compared to urban schools. Urban schools were selected as the reference group primarily because they tend to have larger achievement gains over time than rural schools and smaller achievement gains over time than suburban schools (Roberts & Noble, 2004; Schiel, Pommerich, & Noble, 1996). Effect-coded dummy variables were used for accrediting region so that each region could be compared to the total group; no one region was of interest as a reference group. ACT high school codes were used to identify each high school.

The total sample consisted of 403,381 students from 10,792 high schools. Each student was required to be either a junior or a senior, to have valid PLAN and ACT Composite scores, and had to have valid values for all school characteristic variables.

Method

Means and standard deviations were calculated on all student- and school-level continuous variables. Percentages were calculated for all categorical variables.

Hierarchical linear regression was used to model ACT English, Mathematics, and Science scores. Similarly, hierarchical logistic regression was used to model the probability of students' meeting or exceeding the ACT English, Mathematics, and Science College Readiness Benchmarks. The student-level (level 1) independent variables included the relevant PLAN score, student grade level (11 or 12), and specific course pattern indicators. All analyses were conducted using HLM version 5 (Raudenbush, Bryk, Cheong, and Congdon, 2000).

Two sets of models were developed: The first set of models treated student-level regression coefficients as random effects across high schools, but excluded high school characteristics as predictors of these coefficients. The second set also treated student-level regression coefficients as random effects across high schools, but also included school characteristics as predictors of the level 1 intercepts and slopes. All nonsignificant ($p > .01$) school characteristic variables were dropped from each model.

The linear regression results were evaluated in terms of the change in average ACT scores associated with taking a particular course or course pattern, and the effects of school characteristics on this change. A linear regression coefficient for a particular course (i.e., a student-level variable) can be interpreted as the average increase in ACT score associated with taking the course. Similarly, the school-level variables were coded such that the regression coefficient associated with a certain school characteristic could be interpreted as the typical increase in the average student-level coefficient that was associated with that school characteristic. The level 2 intercept (γ_{i0}) was the student-level regression coefficient averaged across all schools.

The logistic regression results were evaluated in terms of the proportional increase in the odds of meeting or exceeding a particular Benchmark associated with taking a particular course pattern (odds ratio). The odds ratio is the ratio of the odds for the two groups defined by their taking or not taking a particular course or course pattern.

$$\textit{odds ratio} = \frac{p(1)/[1-p(1)]}{p(0)/[1-p(0)]} = e^{\beta}$$

where $p(0)$ = probability of not meeting/exceeding the Benchmark (0), given that a particular course pattern was not taken

$p(1)$ = probability of meeting/exceeding the Benchmark (1), given that a particular course pattern was taken

β = the regression coefficient associated with taking a particular course or course pattern (i.e., estimated log odds of meeting/exceeding the Benchmark), given the other variables in the model.

Coefficients for the level 2 school characteristics were similarly interpreted: They reflected the typical adjustment in the average level 1 regression coefficient (across schools) that was associated with a school characteristic.

Results

Descriptive Statistics

Descriptive statistics for all variables used in the study are shown in Tables 1 and 2. Means and standard deviations, or percentages, are shown for both student-level and school-level variables.

PLAN and ACT mean scores (see Table 1 on following page) were generally higher than those of students nationally (ACT, 2000; 2003). As a result, a higher percentage of students met or exceeded the College Readiness Benchmarks than did students nationally. The majority of students were high school seniors (57%) and Caucasian American (76%).

Almost all students had taken English 9-11, or English 9-11 and one or more foreign languages by the time they took the ACT. Thirty-four percent had taken only Algebra 1, Algebra 2, and Geometry, while 50% had taken additional mathematics course work beyond these three courses. In science, 38% had taken only Biology, but 33% had taken Biology and Chemistry. Only 26% had taken Biology, Chemistry, and Physics.

TABLE 1

Descriptive Statistics for All Student-Level Variables

Variable	Mean	SD	Percentage
Test scores			
PLAN English	18.8	4.46	
PLAN Mathematics	19.0	4.29	
PLAN Science	19.3	3.07	
ACT English	21.3	5.76	
ACT Mathematics	21.2	5.15	
ACT Science	21.5	4.62	
Meets/exceeds English Benchmark			74
Meets/exceeds Mathematics Benchmark			44
Meets/exceeds Science Benchmark			30
Demographic characteristic			
12th grade student			57
African American			9
Caucasian American			76
Hispanic			5
Asian American			3
Other			4
Course work taken			
Less than English 9-11			1
English 9-11			6
English 9-11 & one or more foreign languages			94
Less than Alg. 1, Alg. 2, & Geometry			12
Alg. 1, Alg. 2, & Geometry			34
Beyond Alg. 1, Alg. 2, & Geometry:			
Other Adv Math only			13
Trigonometry only			17
Trig & Other Adv. Math only			11
Trig & Calculus only			4
Other Adv Math, Trig & Calculus			5
General Science			2
Biology			38
Beyond Biology:			
Chemistry			33
Chemistry & Physics			26

As shown in Table 2, the large majority of schools were public schools (82%). Slightly more than half (54%) were rural schools and from the North Central accrediting region. Less than 40% (38%) were multi-high school districts. The average class size was 239 students.

TABLE 2

Descriptive Statistics for All School-Level Variables

Variable	Mean (SD)/ percentage
Class size (in hundreds)	2.39 (2.61)
School type	
Public school	82
Private	18
Urbanicity	
Rural	54
Suburban	26
Urban	20
Region	
South	30
Northwest	5
North Central	56
West	4
Northeast	5
Type of district	
Multi-high school	38
Single high school	62

Modeling ACT Scores: Hierarchical Linear Regression Results

The hierarchical linear regression results excluding school characteristics are shown in Tables 3a-3c. Each table includes the unstandardized regression coefficients for each variable; all regression coefficients were statistically significant ($p < .01$) unless otherwise noted. Across all models except English 9-11 vs. less than English 9-11, variances across high schools for the intercept and slopes (i.e., random effects) were statistically significant ($p < .01$). These results supported the use of hierarchical models with random effects for this study. It should be noted, however, that the variance across high schools for the PLAN score slope, though statistically significant, was small (.01-.03 across all models) relative to the magnitude of the slope (.75 to .99).

As shown in Table 3a, two sets of course work variables were used to model ACT English score: One model included taking English 9-11 (Model 1) and the other included taking both English 9-11 and one or more foreign languages (Model 2). For both models, PLAN English score and grade level were positively related to ACT English score. A one unit increase in PLAN English score corresponded to about a one unit increase in ACT English score. Moreover, high school seniors, on average, scored about .30 to .32 units higher on ACT English than did juniors. Overall, the models explained 58% and 60% of the variance (R^2) in students' ACT English scores.

TABLE 3a

Hierarchical Linear Regression Coefficients for ACT English Score

		Regression coefficient				
Model	**Course work comparison**	**Intercept**	**PLAN English**	**Grade level**	**Course work**	**Level 1 R^2**
1	English 9-11 vs. less than these 3 courses	2.20	.98	.30	-.72	.58
2	English 9-11 & 1 or more foreign languages vs. English 9-11	1.33	.99	.32	1.12	.60

Taking English 9-11 (Model 1) was associated with a .72 decrease in average ACT English score, compared to taking fewer courses, given students' prior achievement and grade level at the time of taking the ACT. This decrease is likely due to the fact that very few students reported taking less than English 9-11 (1%). Since English 9-12 is typically required of all high school graduates, it is likely that these students did not report their actual English course work taken, or were sufficiently advanced that they were not required to take all three courses in high school. In contrast, taking one or more foreign languages over and above English 9-11 (Model 2) increased students' ACT English score, on average, by 1.12 score units, compared to taking only English 9-11.

Table 3b contains the results for ACT Mathematics score. Six models were developed, each with a unique course work variable. Models 2-6 included students taking Algebra 1, Algebra 2, and Geometry as the comparison group to evaluate the contribution of additional courses.

TABLE 3b

Hierarchical Linear Regression Coefficients for ACT Mathematics Score

		Regression coefficient				
Model	**Course work comparison**	**Intercept**	**PLAN Math**	**Grade level**	**Course work**	**Level 1 R^2**
1	Alg 1, Alg 2, and Geometry vs. less these courses	5.03	.75	-.45	1.07	.52
Alg 1, Alg 2, and Geometry vs.						
2	Alg 1, Alg 2, Geometry, & Other Adv Math only	5.65	.79	-.66	1.01	.52
3	Alg 1, Alg 2, Geometry, & Trig only	5.63	.79	-.70	1.52	.59
4	Alg 1, Alg 2, Geometry, Trig & Other Adv Math only	5.91	.78	-.72	2.02	.60
5	Alg 1, Alg 2, Geometry, Trig & Calc only	5.84	.78	-.62	2.91	.60
6	Alg 1, Alg 2, Geometry, Other Adv Math, Trig & Calc	5.90	.77	-.62	3.16	.63

Across all models, a one-unit increase in PLAN Mathematics score was associated with an average ACT Mathematics score increase of .75 to .79. On average, juniors outscored seniors by .45 to .72 score units. The predictor variables explained 52% to 63% of the variance in students' ACT Mathematics scores.

Taking Algebra 1, Algebra 2, and Geometry (Model 1) was associated with an average ACT Mathematics score increase of about 1.1 score units, compared with taking less than these three courses. Taking either Other Advanced Mathematics or Trigonometry (Model 2 or 3), in addition to these three courses, resulted in an average increase in ACT Mathematics score of 1.01 to 1.52 score units. Taking Other Advanced Mathematics and Trigonometry, or Trigonometry and Calculus (Model 4 or 5), increased ACT Mathematics scores, on average, by more than 2.00 score units. The greatest average score increase from mathematics course work resulted from taking Other Advanced Mathematics, Trigonometry, and Calculus (Model 6), in addition to Algebra 1, Algebra 2, and Geometry (3.16 score units).

Table 3c contains the results for ACT Science. Three models were developed, each with a unique course work variable. Models 2 and 3 included students taking Biology as the comparison group to evaluate the contribution of additional courses.

TABLE 3c

Hierarchical Linear Regression Coefficients for ACT Science Score

		Regression coefficient				
Model	**Course work comparison**	**Intercept**	**PLAN Science**	**Grade level**	**Course work**	**Level 1 R^2**
1	Biology vs. General Science	4.70	.78	-.07*	.46	.28
Biology vs.						
2	Biology & Chemistry	4.26	.83	-.43	1.29	.37
3	Biology, Chemistry, & Physics	4.23	.84	-.48	2.41	.47

* $p > .01$

A one unit increase in PLAN Science score was associated with an average ACT Science score increase of .78 to .84. Juniors typically outscored seniors, with ACT Science scores typically .07 to .48 score units higher than those for seniors. Between 28% and 47% of the variance in students' ACT Science scores was explained by these models.

Compared with taking General Science only, taking General Science and Biology, or Biology alone (Model 1), resulted in an average ACT Science score increase of .46. In comparison, taking Biology and Chemistry, or Biology, Chemistry, and Physics (Model 2 or 3), was associated with an average ACT Science score increase of over 1.2 score units, compared to taking only Biology.

Differences in course work effects by school characteristic. The hierarchical linear regression models including school characteristics are provided in Appendix A. These tables include all statistically significant ($p < .01$) effects; non-significant results are not reported, except where multiple dummy variables are used to represent categories of one variable (e.g., region). Non-significant results are noted in these cases. The results including school characteristics showed that the contributions of the level 1 variables to ACT performance differed significantly across school characteristics. For almost all models, the PLAN score regression coefficient differed significantly by region and, for Mathematics, by school type. However, the magnitude of the coefficients for school type was quite small and the coefficients for individual regions were often not statistically significant.

The regression coefficients for grade level showed that the relationship between ACT performance and grade level generally differed across regions. Typically, seniors outscored juniors in the Southern and North Central regions, but juniors outscored seniors in the Northeastern region.

The intercept coefficients illustrate the differences in ACT score across high schools of various types. For example, the results for the first mathematics model showed that public schools, and those from the Southern region, had higher ACT Mathematics scores than those from private schools, or those from other accrediting regions.

For ACT English, the effect of taking English 9-11 did not differ by school characteristic (Model 1). However, the effect of taking English 9-11 and one or more foreign languages differed significantly by school type, location, and region (Model 2). Average score increases associated with taking these courses were greater for private schools, suburban schools, and schools in the Southern and North Central regions.

With the exception of taking Algebra 1, Algebra 2, Geometry, and Other Advanced Mathematics only (Model 2), taking mathematics courses was associated with a larger average ACT Mathematics score increase for students from rural and suburban schools than for those from urban schools. Larger average score increases associated with taking Algebra 1, Algebra 2, and Geometry (Model 1); Other Advanced Mathematics, Trigonometry, and these three courses (Model 4); and Trigonometry, Calculus, and these three courses (Model 5) were also found for students from schools in the North Central accrediting region. Students from schools in the Southern accrediting region had smaller than average score increases associated with taking Algebra 1, Algebra 2, and Geometry (Model 1), but larger increases associated with taking Algebra 1, Algebra 2, Geometry, Trigonometry, and Calculus (Model 5). Students from schools from the Western accrediting region had much smaller than average ACT Mathematics score increases associated with taking Algebra 1, Algebra 2, Geometry, Other Advanced Mathematics, Trigonometry, and Calculus (Model 6).

Taking Biology alone (Model 1), Biology and Chemistry (Model 2), or taking Physics in addition to these two courses (Model 3), was associated with larger average ACT Science score increases for students from rural and suburban schools, and students from schools in the North Central accrediting region (excluding Biology only), than for students from urban schools and those from the Southern, Northwestern, and Western accrediting regions. Taking Biology and

Chemistry, or these two courses and Physics (Models 2 or 3), was also associated with larger than average ACT Science score increases for students from the Northeastern accrediting region.

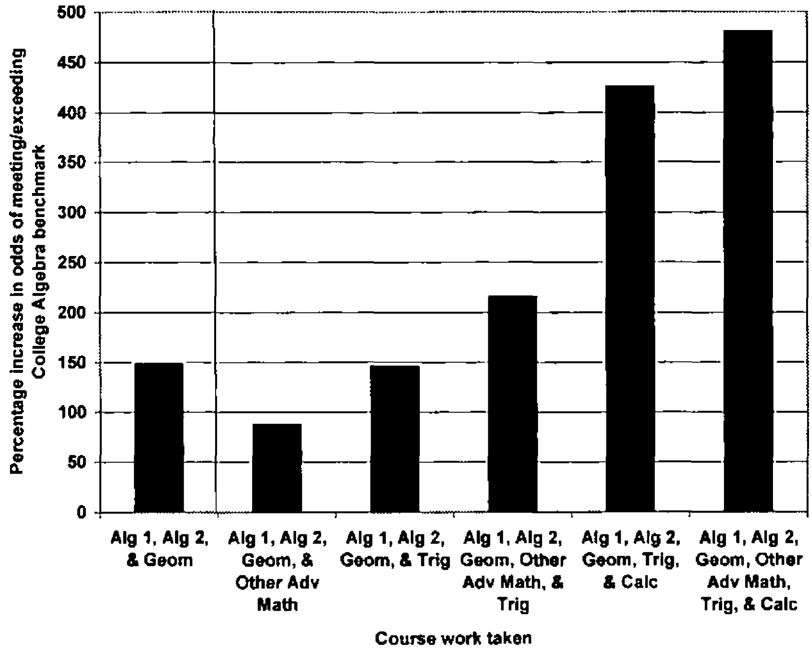
Modeling ACT College Readiness Benchmarks: Hierarchical Logistic Regression Results

The unstandardized logistic regression coefficients are reported in Appendix B1 for models excluding school characteristics. The odds ratios corresponding to particular course work variables are described below.

For the ACT English Benchmark, logistic regression models could not be developed for English 9-11. Very few students took less than English 9-11 and failed to meet the Benchmark. Compared to taking only English 9-11, however, also taking one or more foreign languages was associated with a 97% increase in the odds of students meeting or exceeding the Benchmark.

Figure 1 illustrates the increases in the odds of meeting the ACT Mathematics Benchmark by taking Algebra 1, Algebra 2, and Geometry, as well as taking other courses over and above Algebra 1, Algebra 2, and Geometry. Compared to taking fewer courses, taking Algebra 1, Algebra 2, and Geometry was associated with an increase in the odds of students meeting the Benchmark by 148%. The odds of meeting the Benchmark were about 2½ times greater for students taking these courses, compared to students taking fewer courses.

FIGURE 1. Increase in Odds of Meeting or Exceeding ACT Mathematics Benchmark by Taking Specific Mathematics Course Work



As was found earlier with the linear regression results, taking upper-level mathematics courses beyond Algebra 1, Algebra 2, and Geometry was associated with substantial increases in the odds of students meeting or exceeding the ACT Mathematics Benchmark (by 88% to 481%). In other words, the odds of students meeting the Mathematics Benchmark were 1.8 to about six times greater for students taking these courses, compared to taking only Algebra 1, Algebra 2, and Geometry.

Taking Biology and Chemistry, compared to taking only Biology, was associated with a 103% increase in the odds of meeting or exceeding the ACT Science Benchmark. Compared to taking Biology alone, taking Biology, Chemistry, and Physics increased the odds by 271%. Logistic models could not be developed for Biology alone; too few students taking Biology alone or General Science met the ACT Science Benchmark.

Differences in course work effects by school characteristic. The hierarchical logistic regression models including school characteristics are provided in Appendix B2. These tables include all statistically significant ($p < .01$) effects; non-significant results are indicated with an asterisk (*). As noted above, logistic models could not be developed for Biology alone; too few students taking Biology alone or General Science met the ACT Science Benchmark.

The logistic regression results differed somewhat from the linear regression results. However, school characteristics were still found to influence the relationships between the level 1 predictors and ACT performance. In particular, the association between PLAN score and ACT performance still differed by region (and by school type for ACT Mathematics), though the relationship remained small.

Taking English 9-11 and one or more foreign languages (Model 2) was associated with a greater increase in the odds of meeting the ACT English Benchmark for students from private high schools and single school districts. Regional differences were found for this course sequence, with students from Southern schools who took these courses having greater increases in the odds of meeting the ACT English Benchmark than students from other regions.

Attending a public school was associated with greater increases in odds of meeting the ACT Mathematics Benchmark by taking Other Advanced Mathematics, or Other Advanced Mathematics and Trigonometry (Model 2 or 4), compared to students attending private schools. In contrast, attending a private school was associated with greater odds by taking all six mathematics courses (Model 6). For most of the mathematics course patterns, attending a rural or suburban school was associated with greater odds of achieving the Benchmark than attending an urban school. Regional differences were found for only two mathematics course patterns: Algebra 1, Algebra 2, and Geometry (Model 1), where these courses were associated with higher increases in odds for students from the North Central region, and smaller increases in odds for students from the Southern region, and taking all six courses (Model 6), where greater increases in odds were found for students from schools in the Southern region.

For Science, greater increases in the odds of achieving the Benchmark associated with taking Biology, Chemistry, and Physics (Model 3) were found for students from rural and suburban schools and those from the North Central and Northeastern accrediting regions, compared to students from urban schools or those from other regions. Students from schools in the Northeastern region had similar increases in odds associated with taking Biology and Chemistry only (Model 2). In contrast, taking either set of courses was associated with smaller increases in the odds of achieving the Benchmark for students from the Southern accrediting region. Students who took Biology and Chemistry (Model 2) and were from private schools also had smaller than average increases in the odds of achieving the Benchmark.

Conclusions

The results of this study supported the use of hierarchical modeling for examining relationships between high school course work taken and ACT performance. The benefits of course work taken in high school for ACT performance depended on the high school students attended, regardless of prior achievement and grade level at testing. We found significant variability across high schools in nearly all regression coefficients, thereby supporting the use of hierarchical modeling to address this issue.

Compared to earlier studies, these models explained similar proportions of student-level variance in ACT scores. The magnitude of the regression coefficients are difficult to compare, due to the other variables included in the models and the manner in which the course work variables were coded. However, the overall trends were similar: higher level mathematics and science courses corresponded to greater average increases in ACT Mathematics and Science scores, compared to lower-level courses.

The relationships between course work taken and ACT performance were influenced by the characteristics of schools, most often the accrediting region of the school. These results occurred for virtually all course work variables studied. In addition, overall school means (intercept terms) differed across high schools and high school characteristics, thus arguing for hierarchical models that include level 2 equations for both the intercept and slope terms.

Because the course work variables and models from earlier research differed from those used for this study, it is not possible to make specific comparisons between the results. However, the overall findings here are consistent with other ACT studies where high school attended was used explicitly in the models. Unlike other studies, however, statistical significance tests could be used directly on high school effects to evaluate the implications of specific high school characteristics on slopes and intercept terms.

Implications

Hierarchical modeling is a complex, but versatile approach for evaluating relationships between and among individual- and group-level variables. Single-level models oversimplify the complex nature of such relationships, failing to take into account the numerous factors that affect educational outcomes. With hierarchical modeling, such issues can be addressed with a greater likelihood of finding real differences that are attributable to real events, and not to errors in the models themselves.

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Appendix A
Hierarchical Linear Models Including School Characteristics

ACT English

		Level 2 regression coefficient										
					Location		Accred. region					Multi-school dist.
Model	Level 1	Intercept	Pub vs. priv.	Class size	Rural vs. urban	Suburban vs. urban	South	NW	NC	W	NE	
1	Intercept	2.52	-.40		.04*	.28						
	PLAN English	.97		<.01			-.04	.03	>-.01*	.02*	<-.01*	
	Grade level	.35										
	Eng 9-11 vs. less than Eng. 9-11	-.69										
2	Intercept	.79		.11			-.36	.29*	.23*	-.06*	.28	.28
	PLAN English	1.01					-.02	.01*	-.02	.02*	-.02	-.02
	Grade level	.33		-.04	.18	.07*	.12	-.01*	.04*	.19*	-.34	
	Eng 9-11 & 1 or more foreign lang vs. Eng 9-11	1.29	-.59		-.06*	.26	.54	-.27*	.29	-.64*	.07*	

* p > .01

ACT Mathematics

Model	Level 1	Level 2 regression coefficient: Intercept	Pub vs. priv.	Class size	Location: Rural vs. urban	Location: Suburban vs. urban	Accred. region: South	NW	NC	W	NE	Multi-school dist.
1	Intercept	3.94	.90				.73	-.34*	.19*	-.20*	-.38*	
	PLAN Mathematics	.87	-.10	.01			-.06	.02*	-.04	.04*	.05*	-.01
	Grade level	-.62					.13*	-.07*	.14	.16*	-.37	.10
	Alg 1, Alg 2, & Geom vs. less than these 3 courses	.69			.16	.29	-.24	.19*	.40	-.10*	-.25*	
Alg. 1, Alg. 2, & Geom. Vs												
2	Intercept	5.36		.09								
	PLAN Mathematics	.84	-.05		<.01*	.02	-.03	.01*	-.01*	.02	.01*	-.01
	Grade level	-.92			.14	.03*	.16	-.04*	.18	.07*	-.38	.10
	Alg 1, Alg 2, Geom, Other Adv Math	.89			.22	.09*						
3	Intercept	5.38		.08								
	PLAN Mathematics	.84	-.04				-.03	.01*	>-.01	.02	.01	
	Grade level	-.85					.25	-.07*	.16	.07*	-.42	
	Alg 1, Alg 2, Geom, & Trig	1.16		.05	.33	.34						-.14
4	Intercept	5.84		.08			-.66	.04*	-.09*	.39	.32	
	PLAN Mathematics	.81	-.04									
	Grade level	-1.03			.16	.15	.35	.03*	.19	.11*	-.67	
	Alg 1, Alg 2, Geom, Trig & Other Adv Math	1.64			.35	.36	-.14*	-.02	.16	-.11*	.10*	
5	Intercept	5.55		.08								
	PLAN Mathematics	.82	-.04				-.03	<.01*	>-.01	.02	.01*	
	Grade level	-.73					.20	-.02*	.12*	.14*	-.44	
	Alg 1, Alg 2, Geom, Trig & Calculus	2.18		.05	.46	.38	.22	-.12*	.21	-.33*	.02*	
6	Intercept	5.60		.08								
	PLAN Mathematics	.82	-.04				-.03	<.01*	>-.01	.02	.01*	
	Grade level	-.73					.21	-.02*	.12*	.08	-.38	
	Alg 1, Alg 2, Geom, Other Adv Math, Trig, & Calc	2.80			.33	.35	.12*	.17	.05*	-.48	.15*	

* p > .01

ACT Science

Model	Level 1	Level 2 regression coefficient										
					Location		Accred. region					
		Intercept	Pub vs. priv.	Class size	Rural vs. urban	Suburban vs. urban	South	NW	NC	W	NE	Multi-school dist.
1	Intercept	5.08	-.32									
	PLAN Science	.78					-.03	.04	-.01	.01*	-.01*	
	Grade level	-.33					.16*	-.11*	.35	.02*	-.42*	
	Biology	.21*		.04	.21	.33						-.21
Biology vs.												
2	Intercept	4.51	-.38	.05	.12*	.24						-.36
	PLAN Science	.84					-.03	.04	-.01	.01*	-.01*	
	Grade level	-.75	.17	-.02			.17	-.02*	.24	.03*	-.43	.12
	Biology & Chemistry	1.18	-.28	.04	.23	.21	-.17	-.12*	.16	-.22*	.35	
3	Intercept	3.77	-.17		.93	.96						
	PLAN Science	.87			-.04	-.04	-.03	.03	-.01	.01*	-.01*	
	Grade level	-.57		-.03			.28	.06*	.25	.03*	-.62	
	Biology, Chemistry, & Physics	2.02	-.41	.09	.56	.36	-.23	-.15*	.25	-.51*	.64	

* $p > .01$

Appendix B1

Hierarchical Logistic Models Excluding School Characteristics

ACT English College Readiness Benchmark

Model	Course work comparison	Regression coefficient: Intercept	PLAN English	Grade level	Course work (odds ratio)
1	English 9-11 vs. less than these 3 courses	**	**	**	**
2	English 9-11 & 1 or more foreign languages vs. English 9-11	-8.04	.49	.02*	.68 (1.97)

** Insufficient numbers of students taking less than English 9-11 and not meeting the English Benchmark to calculate.

ACT Mathematics College Readiness Benchmark

Model	Course work comparison	Regression coefficient: Intercept	PLAN Math	Grade level	Course work (odds ratio)
1	Alg 1, Alg 2, and Geometry vs. less than these courses	-10.29	.47	-.37	.91 (2.48)
Alg 1, Alg 2, and Geometry vs.					
2	Alg 1, Alg 2, Geometry, & Other Adv Math only	-9.18	.46	-.40	.63 (1.88)
3	Alg 1, Alg 2, Geometry, & Trig only	-8.91	.44	-.43	.90 (2.46)
4	Alg 1, Alg 2, Geometry, Trig & Other Adv Math only	-8.86	.44	-.42	1.15 (3.16)
5	Alg 1, Alg 2, Geometry, Trig & Calc only	-9.01	.45	-.40	1.66 (5.26)
6	Alg 1, Alg 2, Geometry, Other Adv Math, Trig & Calc	-8.96	.44	-.40	1.76 (5.81)

ACT Science College Readiness Benchmark

Model	Course work comparison	Regression coefficients: Intercept	PLAN Science	Grade level	Course work (odds ratio)
1	Biology vs. General Science	**	**	**	**
Biology vs.					
2	Biology & Chemistry	-10.97	.48	-.29	.71 (2.03)
3	Biology, Chemistry, & Physics	-10.24	.44	-.30	1.31 (3.71)

** Insufficient numbers of students meeting the Science Benchmark to calculate.

Appendix B2

Hierarchical Logistic Models Including School Characteristics

ACT English College Readiness Benchmark

Model	Level 1	Level 2 regression coefficient										
					Location		Accred. region					Multi-school dist.
		Intercept	Pub vs. priv.	Class size	Rural vs. urban	Suburban vs. urban	South	NW	NC	W	NE	
1	Intercept	**	**	**	**	**	**	**	**	**	**	**
	PLAN English	**	**	**	**	**	**	**	**	**	**	**
	Grade level	**	**	**	**	**	**	**	**	**	**	**
	Eng 9-11 vs. less than Eng. 9-11	**	**	**	**	**	**	**	**	**	**	**
2	Intercept	-8.76		.07			.28*	-.07*	.48	-.67*	-.02*	
	PLAN English	.54	-.01				-.04	.03	-.03	.05	-.01*	
	Grade level	.11		-.03	.08	.02*	<.01*	-.02*	-.03*	.27	-.22	
	Eng 9-11 & 1 or more foreign lang vs. Eng 9-11	.69	-.18		>-.01*	.18	.31	-.19*	.10*	-.42*	.21*	-.07

* p > .01

** Insufficient numbers of students taking less than English 9-11 and not meeting the English Benchmark to calculate.

ACT Mathematics College Readiness Benchmark

Model	Level 1	Level 2 regression coefficient										
					Location		Accred. region					
		Intercept	Pub vs. priv.	Class size	Rural vs. urban	Suburban vs. urban	South	NW	NC	W	NE	Multi-school dist.
1	Intercept	-10.61		.06	-.38	.22*						-.15
	PLAN Mathematics	.52	-.03		.02	-.01*	>-.01*	>-.01*	-.02	.01*	.01	
	Grade level	-.41										.09
	Alg 1, Alg 2, & Geom vs. less than these 3 courses	.68					-.26	-.01*	.40	.13*	-.26*	
Alg 1, Alg 2, & Geom. vs.												
2	Intercept	-9.99		.14			-.22*	.18*	.49	.92	-1.38	-.43
	PLAN Mathematics	.53	-.03	>-.01			-.01*	-.01*	-.03	-.03*	.08	.02
	Grade level	-.52			.12	.11						.08
	Alg 1, Alg 2, Geom, & Other Adv Math	.51	.16									
3	Intercept	-9.64		.13	.01*	.13	-.66	.67	.21*	.38*	-.60	-.17
	PLAN Mathematics	.50	-.03	>-.01			.01*	-.03	-.01	>-.01	.03	
	Grade level	-.54					.15	-.12*	.08*	.03*	-.14*	.07
	Alg 1, Alg 2, Geom, & Trig	.76			.20	.16						
4	Intercept	-9.44		.15			-.96	.14*	.08*	.50*	.24*	-.14
	PLAN Mathematics	.50	-.03	>-.01			.03	-.01*	-.01*	-.01*	-.01*	
	Grade level	-.52					.18	-.03*	.11	.08*	-.34	
	Alg 1, Alg 2, Geom, Trig & Other Adv Math	1.00	.20									
5	Intercept	-9.90		.15			-.40	.37*	.38	.58*	-.93	-.17
	PLAN Mathematics	.52	-.03	>-.01			<.01*	-.02*	-.02	-.01*	.05	
	Grade level	-.50			.04*	.12						.11
	Alg 1, Alg 2, Geom, Trig & Calculus	1.53			.27	.13*						
6	Intercept	-9.89		.15			-.21*	.12*	.52	.64*	-1.07	
	PLAN Mathematics	.50		>-.01			-.01*	-.01*	-.03	-.01*	.06	
	Grade level	-.41										.06
	Alg 1, Alg 2, Geom, Other Adv Math, Trig, & Calc	1.69	-.22		.27	.19	.20	.17*	.04*	-.43	.01*	

* p > .01

ACT Science College Readiness Benchmark

Model	Level 1	Level 2 regression coefficient										
					Location		Accred. region					Multi-school dist.
		Intercept	Pub vs. priv.	Class size	Rural vs. urban	Suburban vs. urban	South	NW	NC	W	NE	
1	Intercept	**	**	**	**	**	**	**	**	**	**	**
	PLAN Science	**	**	**	**	**	**	**	**	**	**	**
	Grade level	**	**	**	**	**	**	**	**	**	**	**
	Biology vs. General Science	**	**	**	**	**	**	**	**	**	**	**
Biology vs.												
2	Intercept	-11.13		.04			.10*	-.64	.07*	.71	-.24*	-.14
	PLAN Science	.49					-.01*	.05	-.01*	-.02*	>-.01*	
	Grade level	-.31			.02*	.09						
	Biology & Chemistry	.88	-.22				-.17	-.01*	.08*	-.16*	.27	
3	Intercept	-10.25					-.06*	-.74	-.06*	.73*	.14*	
	PLAN Science	.45					>-.01*	.05	>-.01*	-.03*	-.02*	
	Grade level	-.14	-.19	.02								-.16
	Biology, Chemistry, & Physics	1.13			.11	.16	-.15	-.03*	.18	-.26*	.27	

* p > .01

** Insufficient numbers of students meeting the Science Benchmark to calculate.