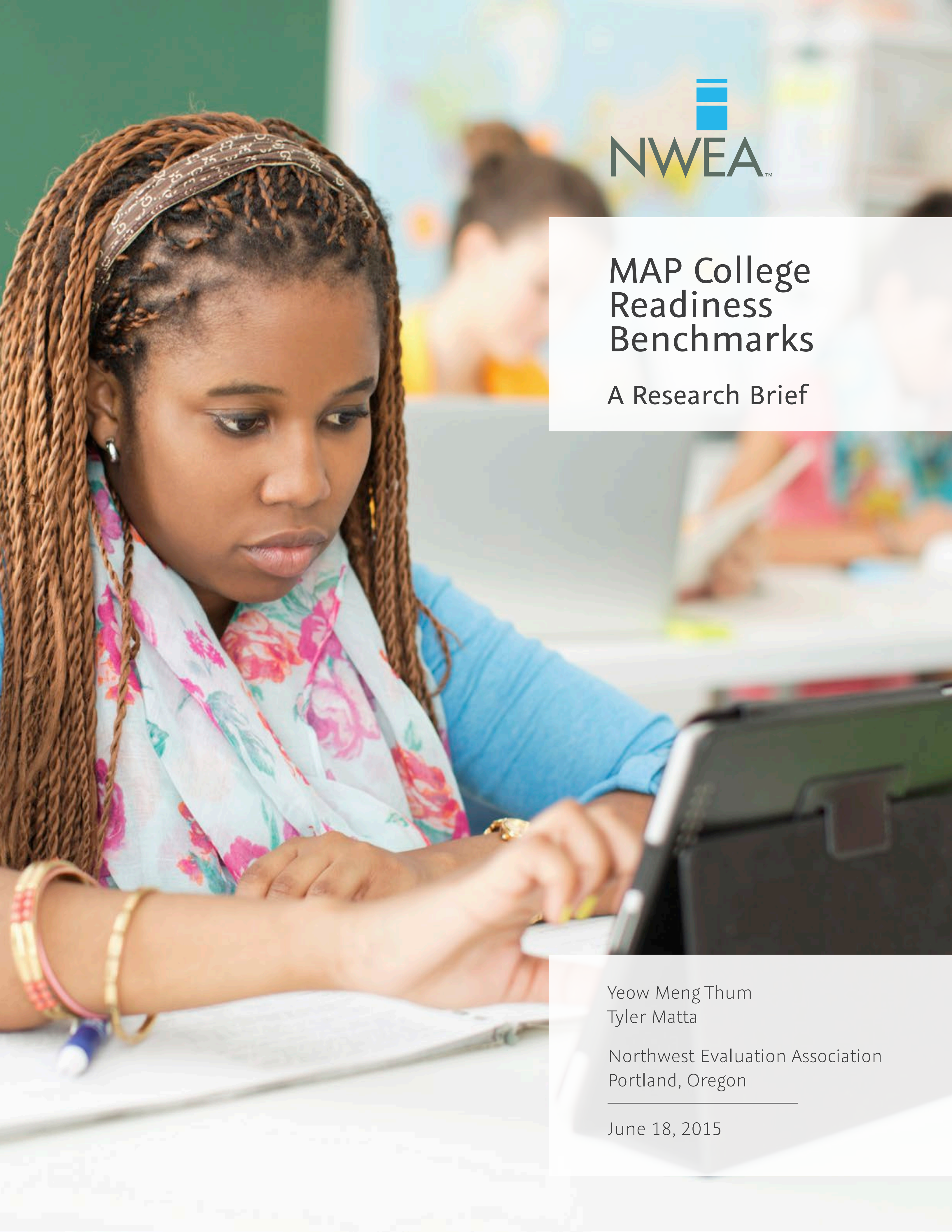

MAP College Readiness Benchmarks

A Research Brief

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June 18, 2015

Suggested Citation:

Thum Y. M., & Matta, T. (2015). *MAP College Readiness Benchmarks: A Research Brief*. NWEA Research Report. Portland, OR: NWEA

MAP College Readiness Benchmarks: A Research Brief*

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June 29, 2015

Preparing students for success in college and the workplace is at the center of educational policy debates across the country. According to a widely-accepted definition (Conley, 2007, p. 5), a student who is college ready is someone who can "enroll and succeed – without remediation – in a credit-bearing general education course at a postsecondary institution that offers a baccalaureate degree or transfer to a baccalaureate program." With college and career readiness as the new focus of K-12 education[1], increasing attention has been given to traditional college entrance examination.

Prospective college applicants typically take the ACT®, SAT®, or both, when they are high school sophomores, juniors, and seniors. A college admissions office would evaluate an applicant's ACT (ACT, 1997) or SAT (The College Board) scores as part of the decision to admit students. More pertinent to this study is that both ACT and The College Board have published benchmarks for their respective tests to address whether students might be college ready (Allen & Sconing, 2005; Kobrin & Michel, 2006). However, college entrance examination results obtained during the end of high school lack utility for educators because it may be too late to help weak-performing high school students make-up the deficit in their preparation for college. To help younger students gauge their preparation prior to taking the ACT, 8th and 9th graders may take EXPLORE® and 10th graders may take PLAN® from ACT's Educational Planning and Assessment Series (or EPAS). Scores from EXPLORE and PLAN not only share the scale of the ACT, they may be used to predict performance on the ACT itself; therefore, indirectly serving as early indicators for college readiness[2]. The Preliminary SAT, or PSAT, from The College Board, plays a similar role for

*We thank Don Draper for leading an immense data collection effort and Branin Bowe for data preparation. Comments from many other colleagues, and specific feedback from Meg Guerreiro, Michael Dahlin, Jim Soland, John Cronin, Carl Hauser, and Gage Kinsbury, significantly improved the report. Opinions expressed in this paper are however the sole responsibility of the authors, as are all remaining errors. Please direct all correspondence to Y. M. Thum, at `yeow.meng@nwea.org`.

[1] See, for example, the President's clarion call identifying college and career preparedness as the goal of US public education (US Department of Education, 2010).

[2] Although the EPAS series has recently been discontinued, its role as a early indicator of college preparedness

students taking the SAT.

For many educators, receiving indications of whether their students are on a track to be college ready earlier in their schooling would be very helpful. Such indicators may inspire students who otherwise may not have thought post-secondary study was a possibility to consider college. Likewise, early indicators of college readiness can enable teachers to identify students who are off-track and put in place the appropriate interventions. Gavin (2011), writing for the Evanston Roundtable in May 2011, described just such an effort in Illinois. The results are back-mapped ACT college readiness benchmarks for grades 3-8 reading and mathematics for the Illinois Standard Achievement Test (ISAT). Northwest Evaluation Association™ (NWEA™) partners similarly recognize the value of college readiness information for Measures of Academic Progress® (MAP®).

Overview

This brief reports a set of college readiness benchmarks for use with MAP reading and mathematics tests from grades 5 through 9[3]. The report also outlines how the study meets some of the data and statistical challenges to arrive at defensible results for MAP users. A fairly diverse group of 14 small to medium-sized school districts from across the country participated in the study. In all, over 621,058 test events from 410 schools that serve a total of 83,318 students are analyzed. Evidence suggests that districts vary in a number of student and school factors (as measured by NWEA's *School Challenge Index*[4], or SCI).

Critical to the benchmarking effort, participating districts also vary widely in the proportion of high school students who take ACT (from about 20% to 70%). It seems reasonable to believe that whether or not a student takes the ACT is not a random outcome but is one that reflects some degree of self-selection. Introducing an approach to mitigate potential self-selection biases in the benchmark estimates is a central contribution of the study.

Generally, the study finds that middle school[5] students are likely to be college ready if they per-

remains important to this discussion. These remarks regarding ACT's EPAS applies to ACT Aspire, which replaces EPAS and extends college readiness assessments into earlier grades.

[3]College readiness is the focus of this work. It is widely-recognized that College and Career Readiness is a much greater challenge, in definition of "success" and its measurement, and is beyond the scope of the research reported here.

[4]The SCI is a school-level indicator of how public schools compare "in terms of the challenges and opportunities they operate under as reflected by an array of factors they do not control" (Northwest Evaluation Association, 2015). This indicator is keyed on the proportion of students who are eligible for a free-and-reduced-priced lunch program in a school. Thus, it generally taps the collective economic circumstance of its students but it also offers a broader view of the "economic strain" they experience, as seen through a relevant set of socio-demographic, organizational, and educational policy programming factors. The SCI ranges from 1 to 99, with higher values for schools serving lesser-privileged student bodies. It has an average of 50 among public schools in the US.

[5]The study addresses grades 5 through 9, which represent more than the standard designation for the middle school grade span. "Middle school" is mostly used in this study for ease of communication.

formed between the 70th to 84th percentiles in mathematics or between the 66th to 75th percentiles in reading[6]. Results also suggest, according to the 2015 achievement norms for MAP, that college readiness benchmarks are more stringent the closer it is to graduation from high school. It is important to stress that the estimated MAP benchmarks are anchored on the ACT score of 24, for both reading and mathematics, a benchmark recommended for use with NWEA partners. This benchmark, which takes into consideration the college admissions profile of enrolled students in major state universities across the country, is more stringent than the widely-circulated ACT college readiness benchmark of 22[7]. For the less stringent ACT = 22 benchmark, middle school students are likely to be college ready if they performed between the 61st to 76th percentiles in mathematics or between the 59th to 69th percentiles in reading on MAP.

The Digest of Educational Statistics estimates of 18.9 and 24.9 are the 25th and 75th percentiles on ACT English for about 1 million freshmen enrolled in public 4-year institutions in 2013 (Snyder & Dillow, 2013, Table 305.40). The interquartile range for ACT Math is given by 19.2 and 24.9. Although an ACT score of 22 is roughly at the middle of this range for both subjects, it is very likely that an ACT score of 22 is not stringent enough as a goal for admissions to modestly selective state universities such as the University of California, Florida, Oregon, South Carolina, or Wisconsin. For many of these universities, the lower quartile of students who were admitted is just above the ACT score of 24. That is, about 75% of entering class for these institutions have an ACT score of 24 or greater. Just being on-track in preparation for college (*i.e.*, the student is predicted to obtain a score of 22 or greater on his ACT) will be a vacuous achievement without also having a measurable likelihood of being admitted to the class of institutions of your choice. To recognize the importance of college admissions standards, targeting an ACT of 24 would seem like a prudent aspirational goal for staying on-track in college preparation. For comparison purposes, MAP college readiness benchmarks corresponding to an ACT score of 22 are also provided.

Using the more stringent MAP college readiness benchmarks (ACT = 24), about 63 to 73 students out of 100 who meet or exceed the benchmarks are correctly classified as college ready and only 10 to 18 students of 100 of those students who are not on-track are misclassified. Similarly, MAP college readiness benchmarks, which assume the ACT college readiness benchmark is 22, about 67 to 75 students out of 100 who meet or exceed the benchmarks are correctly classified as college ready and only 13 to 20 students of 100 of those students who are not on-track are misclassified. These benchmarks are selected with the view that higher misclassification rates of non-college ready students are more costly than the misclassification of college ready student to all stakeholders. Mistaking a student to be on-track when he is not would mean missing the opportunity to intervene and returning him to the path of college preparedness.

[6] All achievement percentiles are from the 2015 RIT Scale Norms for MAP (Northwest Evaluation Association, 2015).

[7] ACT estimates that students meeting or exceeding 22 points on the ACT have a 50% chance of obtaining a grade of "B" or higher or about a 75% chance of obtaining a "C" or higher in corresponding credit-bearing first-year college courses.

Table 1: Illustrative Cohort Structure for a District

	2003		2004		2005		2006		2007		2008		2009	
Grade	Fa	Sp	Fa	Sp	Fa	Sp	Fa	Sp	Fa	Sp	Fa	Sp	Fa	Sp
12	1	1	2	2	3	3	4	4	5	5	6	6	7	7
11	2	2	3	3	4	4	5	5	6	6	7	7	8	8
10	3	3	4	4	5	5	6	6	7	7	8	8	9	9
9	4	4	5	5	6	6	7	7	8	8	9	9	10	10
8	5	5	6	6	7	7	8	8	9	9	10	10	11	11
7	6	6	7	7	8	8	9	9	10	10	11	11	12	12
6	7	7	8	8	9	9	10	10	11	11	12	12	13	13
5	8	8	9	9	10	10	11	11	12	12	13	13	14	14
4	9	9	10	10	11	11	12	12	13	13	14	14	15	15

Note: Used with permission from Thum & Matta (2015).

These robust classification accuracy rates are achieved through the use of all relevant longitudinal student MAP scores within each district and adjustments are made for self-selection in college admissions test-taking practices. Benchmarks that are generally applicable to middle-school students are the result. The study also provides a rationale for aggregating the benchmarks from individual districts for use with the wider MAP partner-base. Finally, ways with which the benchmarks may be used (a) to give the comparative standing of the middle school student in terms of his college readiness in relation to his peers and (b) to ascertain whether a student has met or exceeded a benchmark are suggested.

Data and Design

Longitudinal, as opposed to cross-sectional, data hold the most information for describing and predicting individual and collective growth in learning. This study employed MAP and ACT assessments for mathematics and reading from multiple age-cohorts of students from 14 school districts across the US. From each district, the study uses data from age-cohorts of 4^{th} through 12^{th} grade students to provide the requisite MAP results (grades 4 through 9 only) and, if available, their ACT results in high schools. Fall and spring MAP scores are available for each grade. For the illustrative district data-layout in Table 1, Cohorts 6 through 9 will be selected for analysis although only Cohorts 6 and 7 contribute to benchmark estimation because these student have ACT scores. For the students in Cohorts 8 and 9, only their MAP scores from grade 4 through 9 contribute to the estimation of the MAP score trends from the 4^{th} through the 9^{th} grade.

Table 2 provides the counts of students, schools, MAP Reading test events, and cohorts per district. Districts ranged in cohort size from large (District 10, $N = 6,545$) to small (District 13, $N = 113$). A total of 83,318 students from 410 schools, in 52 cohorts were used to estimate the MAP reading

Table 2: Descriptive statistics for the 14 districts in the study: MAP Reading

	Count				Take ACT	SCI	
District	Schools	Students	Tests	Cohorts	%	Mean	SD
1	57	15148	111007	4	66	51	32
2	10	2067	15868	3	58	42	10
3	18	3760	23635	4	51	59	4
4	12	2013	15998	3	67	55	5
5	10	1300	8173	4	54	60	5
6	30	8784	31200	4	49	39	13
7	27	3243	28838	3	56	35	12
8	18	1464	10990	3	61	41	9
9	17	3296	19121	4	24	38	13
10	106	19635	148857	3	23	47	14
11	55	14816	89022	4	19	53	7
12	31	6132	108894	3	30	37	13
13	10	565	2977	5	76	37	7
14	9	1095	6478	5	61	38	8
Summary	410	83318	621058	52	50*	46†	18†

Note: * total † pooled estimate

and mathematics college readiness benchmarks. Additionally, the proportion of students taking the ACT varied across districts with 76% of students taking the ACT in District 13 and 19% of students taking the ACT in District 11. On average, across all 14 districts, more than half of the graduating class completed the ACT during high school. The counts for MAP Mathematics are highly comparable.

Are districts comparable and how well do they collectively "represent" typical middle school students in the US? The data suggest, not surprisingly, that students performed quite differently on MAP and ACT among the districts. It is clear that some districts have more higher performing students than others. In addition, districts are compared in terms of the average SCI. As Table 2 shows, participating districts have average SCIs from 35 to 60, values that cluster around the national average of 50. It seems reasonable to infer that the participating district schools collectively serve a spectrum of public school students clustered at the national SCI average. Consequently, these results are representative of districts in this more limited sense of the term, rather than being statistically representative of public schools across the US.

Missing Data and Selection

In this study, each district provides all the ACT data from district archives. NWEA receives permission to extract all available MAP scores for use in the study. As a result, ACT data are in

Table 3: Sample Size and Correlation between ACT and MAP for a Single Cohort from District 11

		6		7		8		9		
		Fa	Sp	Fa	Sp	Fa	Sp	Fa	Sp	ACT
Mathematics	N	594	611	639	648	678	687	171	688	801
	Corr.	0.71	0.73	0.72	0.76	0.75	0.78	0.67	0.77	
Reading	N	593	611	1117	1127	1180	1201	206	1159	1375
	Corr.	0.66	0.66	0.67	0.65	0.70	0.68	0.64	0.65	

truth "complete" except for those students who have not taken the college test during high school. Recently, Thum and Matta (2015) found that only about a third of recent graduates in a medium-sized district take either the ACT or the SAT. This pattern is echoed in Table 2. While on average, those who take the ACT also have stronger MAP score trends than those who have not taken the ACT, there is a good proportion of students who do not take the ACT but show MAP score trends that are comparable to students who have taken the college admissions test. Neglecting the MAP scores of these students (that is, ignoring self-selection in test-taking) may lead to biases in the estimated benchmarks. MAP scores are also missing for some students, although in much smaller proportion and appear to be haphazard in their occurrence. Missing MAP data, therefore, are not expected to bias the results and may be ignored.

Correlations between MAP and ACT scores provide the basis for relating one scale to another. Table 3 shows the sample correlations of seniors from one cohort in District 11 who have taken the ACT and MAP scores they received when they attended middle school. The sample correlations are moderately high (from 0.65 to 0.78) but they do not show a trend towards higher values in the higher grades as one expects. Not only do the counts reflect self-selection from the start, there is a pattern of "reverse attrition" in the number of scores available that makes information from bivariate analyses weak. These patterns in the observed data are the very reason why selection needs to be factored into any reasonable approach. It also suggests that growth modeling of longitudinal data is superior to bivariate or cross-sectional analyses. With a longitudinal design, shared information across the grades and terms is maximized and estimates of the links between early MAP scores and ACT are improved.

Linking Method

Many methods are available for relating scores from any two scales for a population of examinees. A delineation of the factors leading to each plausible approach and the significance of its results are beyond the scope of this brief. The interested reader should consult, for example, Kolen (2004). According to the framework shared by Mislevy (1992) and Linn (1993), this application is best considered a projection to the extent that the tests do not tap the same construct and regression is key for constructing the benchmarks. However, several considerations regarding the data are unique to this application.

First, the study seeks to relate scores from two scales (MAP, ACT) obtained over an extended period (grades 5-12), as is also the case with the Illinois ISAT described above. Most applications involve two scales measuring two similar constructs and the scores are obtained at about the same time-frame for a known examinee population. A frequently cited example is the effort to estimate the concordance of scores between the ACT and SAT, but concordance is unsuitable for use in what turns out to be essentially a projection or prediction problem. In relating MAP scores to the ACT however, instead of studying the bivariate relationship using conventional regressions between, for example, the 5th grade MAP mathematics scores with the ACT scores for the population of *all* examinees, the approach in this study considers the entire score trajectory of every individual member of the student population in order to maximize the shared information across time points.

Second, the study recognizes that not all members of a graduating class take a college entrance examination. Scale relationships based only on the data of examinees who have taken a college entrance exam are likely to contain an element of selection bias that generally makes the relationship obtained for college entrance examinees unsuitable for predictive use among the entire student population. For example, it is hard to predict if a 5th grader will opt to take a college entrance examination during high school. Instead, what is needed is information, derived from the available data, about the likelihood of a student taking a college entrance exam in order to identify a relevant benchmark for the grade. Given the challenges posed by the need to employ longitudinal test scores from multiple scales, a special analysis is required to achieve sound results.

The core of the analysis is built on a multilevel growth model that allows examination of multiple sequential age-cohorts of students and jointly considers the impact of selection on the results. From the growth curve estimates, the joint distribution of a set of MAP and ACT scores from multiple age-cohorts of examinees is determined. Inferences for the individual student at any grade and term are based on the estimated multivariate-normal distributions of MAP scores. These distributions are conditional on selected ACT benchmarks and a stated probability of a student taking the college entrance exam in high school (by grade and term). Many elements of the approach are discussed in the literature on statistical inference for longitudinal data in the presence of missing data and selection (e.g., Albert & Follmann, 2009; Hedeker & Gibbons, 1997; Little, 2008).

Following Thum (2011), the recent paper by Thum and Matta (2015) provides the methodological basis for the analyses performed in this study. They successfully deployed this approach for obtaining back-mapped college readiness benchmarks for MAP mathematics and reading based on both the ACT and SAT scores that were available. Appendix A provides a summary of the approach. Recognizing the potential for seasonal bias (and hence auto-correlated errors), a new functional form – constructed from an additive polynomial describing between grade features of within grade level changes – is introduced in place of the more conventional polynomial regression model. In addition, adjustment is also made to reflect the measurement error in MAP and ACT scores. It is important to note that, due to the presence of selection effects, the estimated benchmarks are dependent on the probability that a student takes the college test in high school. This probability is set at 0.5 throughout to represent the very reasonable situation where the user wishes to suppress any such knowledge, even if it is available subjectively, when evaluating the college readiness of middle school students. Finally, the approach demonstrated by Thum (2011) and Thum and Matta (2015) for data from a single district is extended in this study to produce a set of benchmarks from pooling the benchmarks of individual districts.

Results

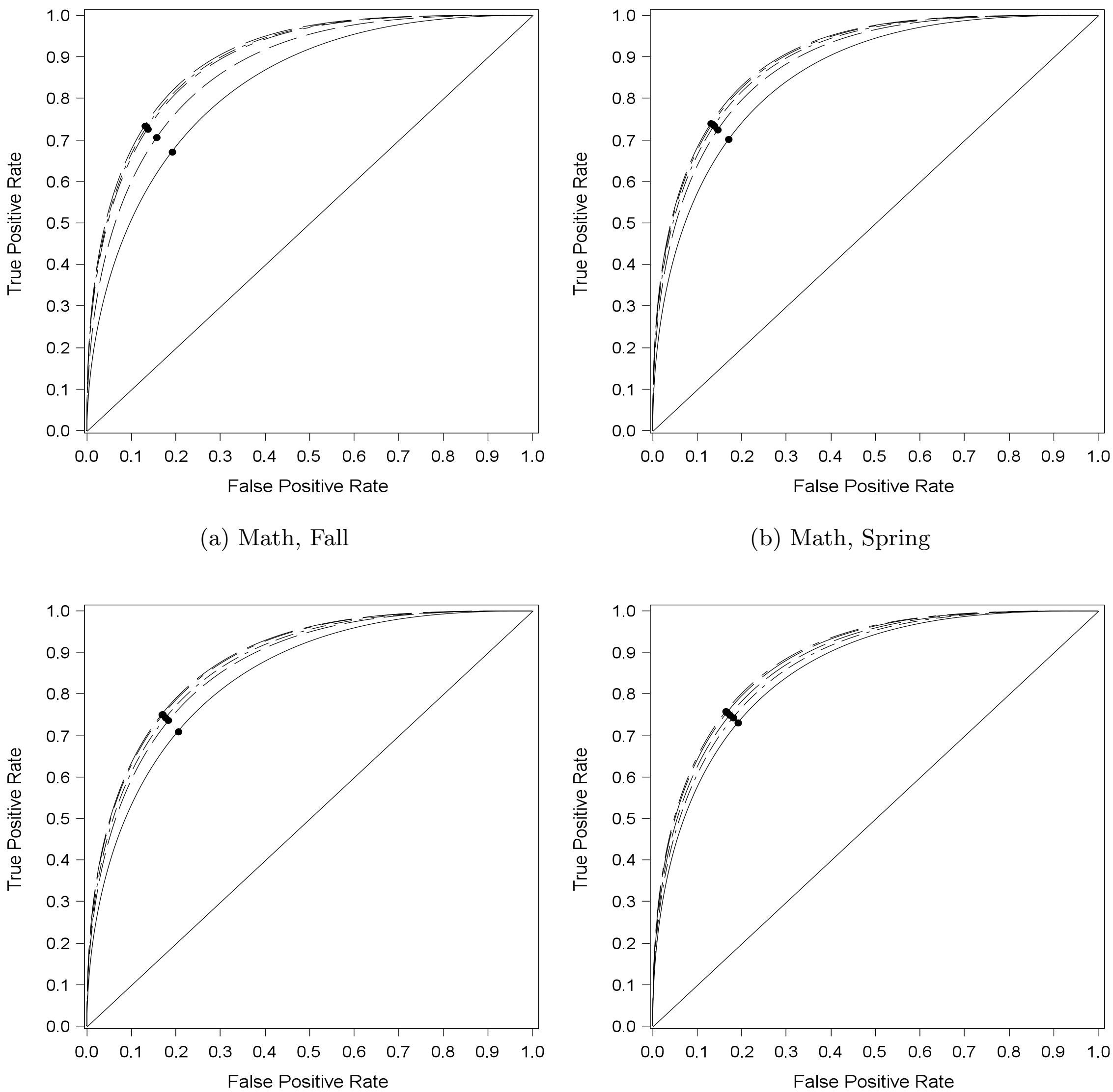
Exploratory analysis of the data for each of the 14 districts consistently suggested that high school students whose MAP scores on reading or mathematics are higher than the district average achievement in the spring of the 8^{th} grade are more likely to take the ACT. The selection model is then specified in a manner to exploit this information. The resulting model estimates are used to derive the college readiness benchmarks (see Appendix A).

Benchmarks

To set the MAP college readiness benchmark for mathematics and reading at each grade and term, given an ACT score of 22 or 24 and a 0.5 probability[8] that a student will opt to take a college test, are examined. Using the estimated bivariate relationships between each MAP assessment and the ACT, benchmarks are identified by considering two classification accuracy standards. The first is the *true positive rate* (TPR) and the second is the *false positive rate* (FPR)[9]. The true positive rate is the proportion of students who are considered college ready based on a given MAP score for a grade and term and who are actually college ready (based on a score of 24 (or 22) or better on the ACT during high school), among all those students who scored a 24 (or 22) or better on the ACT. The false positive rate is the proportion of students who are considered college ready based on a given MAP score but do not score a 24 (or 22) or higher on the ACT among all those students who did not score a 24 (22) or better on the ACT. Locating a MAP score that balances high true positive rate with low false positive rate is key to determining a benchmark for each term and grade.

[8] This probability value merely reflects the situation in which the reader has no specific knowledge about how likely a student will be taking the ACT in high school.

[9] In the wider research literature on decision quality, false positive rate is the Type I error rate and false negative rate is the Type II error rate.



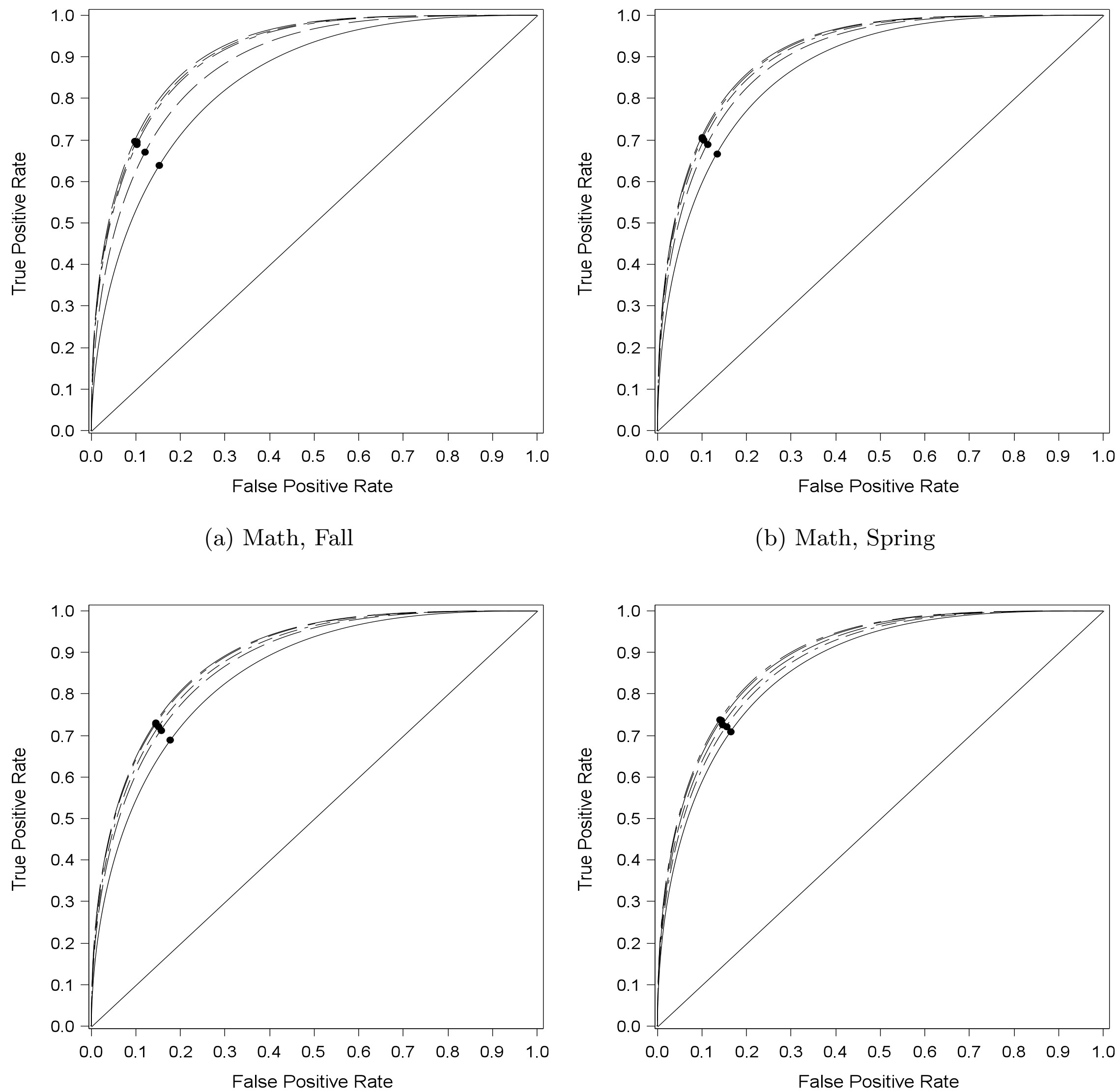
(a) Math, Fall (b) Math, Spring

(c) Reading, Fall (d) Reading, Spring

Figure 1: ACT = 22 ROC Plots for Mathematics and Reading Benchmarks, Grades 5 - 9

Plotting the true positive rate against the false positive rate for all possible MAP benchmarks for a given grade and term generates an ROC curve[10]. The area under the ROC curve (AUC) is a well-known measure of predictive power, where a straight 45-degree line represents no predictive power (or 50-50 chance) and an AUC of 1 is perfect prediction[11]. As is shown in Table 4, AUC estimates for all benchmarks are relatively high, indicating predictions are well calibrated (or reliable).

[10] A "receiver operating characteristic" or ROC curve is a graphical device representing the trade-off between the hit and false alarm rates of a binary decision rule; here, the proposed benchmark for college readiness. See, *e.g.*,



(a) Math, Fall

(b) Math, Spring

(c) Reading, Fall

(d) Reading, Spring

Figure 2: ACT = 24 ROC Plots for Mathematics and Reading Benchmarks, Grades 5 - 9

Figure 1 provides four graphs, each one containing the ROC curves for grades 5 through 9 for different subjects (mathematics and reading) and terms (fall and spring) on assuming the ACT benchmark of 22. Figure 2 displays the same graphs if we assume the more stringent ACT college readiness benchmark of 24. Graph (a) illustrates the ROC curves for fall term mathematics, Graph (b) illustrates spring term mathematics, Graph (c) illustrates fall term reading, and Graph (d) represents spring term reading. In each graph, the grade 5 scores are the shallowest (smaller AUC)

Swets, Dawes, and Monahan, (2000).

[11]The AUC is also called a "concordance" statistic.

Table 4: Area Under the Curve (AUC) for MAP College Readiness Benchmarks

		Grade	5		6		7		8		9	
Subject	ACT	Term	f	s	f	s	f	s	f	s	f	s
Reading	22		0.873	0.886	0.892	0.901	0.902	0.908	0.904	0.906	0.897	0.896
	24		0.879	0.893	0.898	0.907	0.909	0.914	0.910	0.912	0.904	0.902
Mathematics	22		0.866	0.887	0.896	0.906	0.912	0.917	0.917	0.919	0.914	0.914
	24		0.877	0.897	0.906	0.916	0.922	0.926	0.927	0.928	0.924	0.923

and are represented by the solid curved line. As the grade level increases, the AUC becomes larger and the curve approaches the top-left corner of the plot. This indicates, as expected, that benchmarks at 8^{th} and 9^{th} grade are more predictive of college readiness than benchmarks in 5^{th} grade. On the whole, use of the benchmarks leads to highly accurate predictions. The point plotted on each curve is the MAP benchmark with the given true positive rate and false positive rate in Table 5.

In addition to the pooled benchmarks for each grade, term and subject listed in Table 5 are their standard errors, 2015 normative percentiles, true positive, and false positive rates. The standard errors indicate that the benchmarks are well-estimated. As expected, benchmarks increase with grade level and they also appear to be more stringent, as they approach high school. For example, the mathematics benchmark (corresponding to the ACT score of 24) for fall term of grade 7 is 236.84 which corresponds with the 79^{th} percentile based on the 2015 NWEA MAP national norms. Using this benchmark will correctly classify students who are college ready 68% of the time while falsely classifying students who are not college ready as college ready only 10% of the time. The true positive rate for mathematics ranges from 0.63 (fall, grade 5) to 0.70 (spring, grade 7; fall, grade 8; spring, grade 8; spring, grade 9). The false positive for mathematics benchmarks ranges from 0.15 (fall, grade 5) to 0.10 (fall, grade 7 and on). The true positive rates for reading benchmarks range from 0.70 to 0.73 and the false positive rates range from 0.18 to 0.13. Table 5 also gives the results corresponding to the ACT benchmark of 22.

Applications

Rather than use a cut-score to make a simple pronouncement of whether a student is college ready or not, inference statements that provide a suitable normative context and acknowledges that data quality precludes such deterministic characterization are to be preferred (Maruyama, 2012). Specifically, two types of inferences are useful based on the estimated benchmarks for students: comparison with peers and evaluating college readiness.

Table 5: Normative Stringency and Classification Accuracy of Pooled Benchmarks for MAP Mathematics and Reading Tests

		Mathematics, ACT=22					Mathematics, ACT=24				
Grade	Term	Benchmark	SE	Pct	TPR	FPR	Benchmark	SE	Pct	TPR	FPR
5	Fall	217.31	0.04	65	0.67	0.19	221.33	0.04	74	0.63	0.15
5	Spring	225.58	0.04	61	0.70	0.16	229.74	0.04	70	0.67	0.14
6	Fall	225.30	0.04	68	0.70	0.15	229.63	0.04	79	0.68	0.13
6	Spring	232.34	0.03	66	0.72	0.14	236.82	0.03	76	0.68	0.11
7	Fall	232.20	0.03	71	0.72	0.13	236.84	0.03	81	0.68	0.10
7	Spring	238.06	0.03	70	0.73	0.13	242.85	0.03	79	0.70	0.10
8	Fall	238.00	0.03	74	0.73	0.13	242.96	0.03	83	0.70	0.10
8	Spring	242.73	0.04	74	0.73	0.13	247.83	0.04	81	0.70	0.10
9	Fall	242.72	0.04	76	0.73	0.13	247.99	0.04	84	0.69	0.10
9	Spring	246.35	0.04	74	0.73	0.13	251.76	0.04	83	0.70	0.10
		Reading, ACT=22					Reading, ACT=24				
Grade	Term	Benchmark	SE	Pct	TPR	FPR	Benchmark	SE	Pct	TPR	FPR
5	Fall	209.31	0.04	59	0.71	0.20	212.62	0.04	69	0.70	0.18
5	Spring	214.70	0.04	59	0.72	0.18	217.94	0.04	66	0.72	0.17
6	Fall	214.97	0.04	61	0.73	0.18	218.32	0.04	68	0.72	0.16
6	Spring	219.59	0.03	61	0.74	0.17	222.87	0.03	69	0.73	0.15
7	Fall	219.83	0.03	64	0.74	0.17	223.21	0.03	71	0.73	0.15
7	Spring	223.73	0.03	65	0.75	0.16	227.04	0.03	72	0.73	0.13
8	Fall	223.88	0.03	67	0.75	0.16	227.31	0.03	73	0.73	0.14
8	Spring	227.10	0.03	67	0.75	0.16	230.46	0.03	74	0.73	0.14
9	Fall	227.14	0.04	67	0.74	0.17	230.61	0.04	75	0.73	0.16
9	Spring	229.72	0.04	69	0.74	0.17	233.11	0.04	75	0.72	0.15

Note: SE = Std. Error Pct = Percentile TPR = True Positive Rate FPR = False Positive Rate

How Do I Compare With My Peers? The student's observed score may be used to characterize his performance, in terms of a percentile, among his peers who are expected to meet or exceed the ACT college readiness benchmark of 24. Such percentile ranks can be helpful to the efforts to keeping the student on-track for college. Predicted MAP scores, $\hat{y}$, corresponding to selected percentile ranks for MAP benchmarks for reading at grades 5 through 9, for both the fall and spring terms, are given in Table 2. They are easily obtained from the equation

$$\hat{y} = \mu + \sigma \times \Phi^{-1}(P/100) ,$$

where P is the desired percentile, under the assumption that scores are normally distributed with cumulative function $\Phi(\mu, \sigma^2)$ with benchmark μ and variance σ^2. Tables 6, 7, 8, and 9 in Appendix B give the results for mathematics and reading, assuming an ACT of 22 and 24, respectively. The predicted standard deviations reported in these tables are based on conditional distributions given by Equation 5 in Appendix A.

As a more concrete example, the mathematics benchmarks keyed on ACT = 24 (229.63) in Table7 are used to determine that a 6^{th} grade student who scores a 236 on the fall administration of MAP (6 points higher than the benchmark) would be in the 75^{th} percentile amongst 5^{th} graders in terms of being on-track for college. Similarly, a student who scores a 228 (2 points lower than the benchmark) is at the 45^{th} percentile. The student who scores a 230, right at the fall 6^{th} grade MAP college readiness benchmark, would be in the 50^{th} percentile.

Am I College Ready? Direct numerical comparisons are seldom justifiable when working with imperfect information. Probability statements, on the other hand, provide a suitable normative context and acknowledges data quality. The student's observed score and standard error support a simple evaluation, one that takes into account the imprecision of an observed score to determine whether or not his performance meets or exceeds the relevant MAP college readiness threshold. The probability that an observed score y with an SEM[12] s_y meets or exceeds a given benchmark μ is

$$p = \Phi\left[(y - \mu)/s_y\right] \ .$$

Table 10, 11, 12, and 13 in Appendix B give the results for mathematics and reading, assuming an ACT of 22 and 24, respectively, where the default SEM values of 3.2 (for mathematics) and 3.4 (for reading) are employed.

Continuing with the previous example involving the fall administration of 6^{th} grade MAP and ACT = 24, Table 11 shows that the student who scored a 236, when considering the standard error of measurement (SEM=3.2), would have a 98% chance of meeting the benchmark. At the same time, the student who scored a 228 would have a 31% chance of meeting the fall 6^{th} grade benchmark given the same standard error of measurement. The student who scored 230 would have a 55% chance of meeting the benchmark.

Summary

This study identifies some limitations of conventional approaches to linking multiple scales for deriving a set of accurate MAP benchmarks for identifying the college readiness of middle grade students. The method developed by Thum (2011) and Thum and Matta (2015) are employed, and are further extended to include a strategy for pooling the results from multiple districts. The approach successfully addressed serious challenges stemming from the fact that the linked tests do not measure the same construct to begin with, that the tests are less and less likely to do so as the time separating them increases, and that some of the test scores are unobserved due to significant

[12] SEM stands for standard error of measurement. It is a positive number, and scores with smaller SEMs have greater precision. The typical SEMs for MAP mathematics and reading have been found to be 3.2 and 3.4, respectively.

and non-ignorable effects of student self-selecting to take the ACT in high school.

Using over a half million test events from 83,318 4^{th} to 12^{th} graders from 410 schools in 14 districts across the US, pooled college readiness benchmarks for fall and spring terms of 5^{th} through 9^{th} graders on MAP mathematics and reading, which are statistically anchored on ACT's college readiness cut-scores of 22 and 24, are obtained. The true positive classification rates are sufficiently high, suggesting that, when such benchmarks are used, educators and parents can be confident that students are accurately identified as being college ready, or not. At the same time, the false positive classification error rates appear sufficiently low so that students requiring assistance to get back on track to being college ready are also accurately identified.

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Suggested Citation:

Thum Y. M., & Matta, T. (2015). *MAP College Readiness Benchmarks: A Research Brief.* NWEA Research Report. Portland, OR: NWEA

Appendix A

A Growth Model with Selection

For each examinee i, the probability $p(\cdot)$ that they take a college entrance exam ($r_i = 1$) during high school is

$$\Pr(r_i = 1|\boldsymbol{\nu}_i^o) \sim \text{Bernoulli}(f(\boldsymbol{\nu}_i^o)) \ , \tag{1}$$

where $\boldsymbol{\nu}_i^o \in \boldsymbol{\nu}_i$ are residuals from the growth model

$$\Pr(\boldsymbol{y}_{1i}, \boldsymbol{y}_{2i}|\mathbf{X}_i, \boldsymbol{\gamma}, \boldsymbol{\nu}_i, \boldsymbol{\Sigma}_i) \sim \text{Normal}(\mathbf{X}_{1i}\boldsymbol{\gamma} + \mathbf{X}_{2i}\boldsymbol{\nu}_i, \boldsymbol{\Sigma}_i) \tag{2}$$

The product of the marginal distribution of the data under Equation 2 and the conditional probability of a student who takes a college entrance test in high school from Equation 1 defines the shared-parameter model

$$f_y(\boldsymbol{y}_{1i}, \boldsymbol{y}_{2i}|\mathbf{X}_i, \boldsymbol{\gamma}, \boldsymbol{\nu}_i, \boldsymbol{\Sigma}_i) \times f_{r|y}(r_i|\boldsymbol{\nu}_i^o) \tag{3}$$

Let $\dot{p}$ be a suitably chosen probability that a student would take a college entrance examination when he reaches high school. For a given probability $\dot{p}$,

$$(\hat{\boldsymbol{y}}_{1i}, \hat{\boldsymbol{y}}_{2i}|\dot{p}) \sim \text{MVN}\left([\hat{\boldsymbol{\mu}}_1, \hat{\boldsymbol{\mu}}_2], \left[\hat{\boldsymbol{\Sigma}}_{11}, \hat{\boldsymbol{\Sigma}}_{21}, \hat{\boldsymbol{\Sigma}}_{22}\right]\right) \tag{4}$$

is a conditional distribution of predicted student MAP and college entrance examination scores by term and grade-level. The benchmarks on MAP for every term and grade-level, which correspond to the benchmarks $\boldsymbol{y}_2^c$ on the college entrance examinations, are obtained from Equation 4 by further conditioning on $\hat{\boldsymbol{y}}_{2i} = \boldsymbol{y}_2^c$, giving

$$(\hat{\boldsymbol{y}}_{1i}|\hat{\boldsymbol{y}}_{2i} = \boldsymbol{y}_2^c, \dot{p}) \sim \text{MVN}\left(\hat{\boldsymbol{\mu}}_1 + \hat{\boldsymbol{\Sigma}}_{12}\hat{\boldsymbol{\Sigma}}_{22}^{-1}[\hat{\boldsymbol{\mu}}_2 - \boldsymbol{y}_2^c], \hat{\boldsymbol{\Sigma}}_{11} - \hat{\boldsymbol{\Sigma}}_{21}\hat{\boldsymbol{\Sigma}}_{22}^{-1}\hat{\boldsymbol{\Sigma}}_{21}\right) \ . \tag{5}$$

A set of pooled benchmarks is estimated by weighting district-specific benchmarks, represented by Equation 5, by the information provided by the students who contributed their data to each district analysis.

Appendix B

Table 6: Predicted Benchmark for MAP Mathematics by Grade/Term and Percentile Ranks for HS Seniors Expected to Meet the Mathematics ACT=22 Benchmark

	Grade	5		6		7		8		9	
	Term	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
	Benchmark	217.31	225.58	225.30	232.34	232.20	238.06	238.00	242.73	242.72	246.35
	SD	11.46	10.38	10.01	9.59	9.41	9.40	9.61	9.87	10.53	10.99
	Pct	65	61	68	66	71	70	74	74	76	74
Conditional Percentile Rank	10	203	212	212	220	220	226	226	230	229	232
	15	205	215	215	222	222	228	228	233	232	235
	20	208	217	217	224	224	230	230	234	234	237
	25	210	219	219	226	226	232	232	236	236	239
	30	211	220	220	227	227	233	233	238	237	241
	35	213	222	221	229	229	234	234	239	239	242
	40	214	223	223	230	230	236	236	240	240	244
	45	216	224	224	231	231	237	237	241	241	245
	50	217	226	225	232	232	238	238	243	243	246
	55	219	227	227	234	233	239	239	244	244	248
	60	220	228	228	235	235	240	240	245	245	249
	65	222	230	229	236	236	242	242	247	247	251
	70	223	231	231	237	237	243	243	248	248	252
	75	225	233	232	239	239	244	244	249	250	254
	80	227	234	234	240	240	246	246	251	252	256
	85	229	236	236	242	242	248	248	253	254	258
	90	232	239	238	245	244	250	250	255	256	260

Note: Pct = Percentile

Table 7: Predicted Benchmark for MAP Mathematics by Grade/Term and Percentile Ranks for HS Seniors Expected to Meet the Mathematics ACT=24 Benchmark

Grade	5		6		7		8		9	
Term	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Benchmark	221.33	229.74	229.63	236.82	236.84	242.85	242.96	247.83	247.99	251.76
SD	11.58	10.49	10.16	9.73	9.59	9.57	9.83	10.07	10.78	11.23
Pct	74	70	79	76	81	79	83	81	84	83
Conditional Percentile Rank										
10	206	216	217	224	225	231	230	235	234	237
15	209	219	219	227	227	233	233	237	237	240
20	212	221	221	229	229	235	235	239	239	242
25	214	223	223	230	230	236	236	241	241	244
30	215	224	224	232	232	238	238	243	242	246
35	217	226	226	233	233	239	239	244	244	247
40	218	227	227	234	234	240	240	245	245	249
45	220	228	228	236	236	242	242	247	247	250
50	221	230	230	237	237	243	243	248	248	252
55	223	231	231	238	238	244	244	249	249	253
60	224	232	232	239	239	245	245	250	251	255
65	226	234	234	241	241	247	247	252	252	256
70	227	235	235	242	242	248	248	253	254	258
75	229	237	236	243	243	249	250	255	255	259
80	231	239	238	245	245	251	251	256	257	261
85	233	241	240	247	247	253	253	258	259	263
90	236	243	243	249	249	255	256	261	262	266

Note: Pct = Percentile

Table 8: Predicted Benchmark for MAP Reading by Grade/Term and Percentile Ranks for HS Seniors Expected to Meet the Reading ACT=22 Benchmark

Grade	5		6		7		8		9	
Term	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Benchmark	209.31	214.70	214.97	219.59	219.83	223.73	223.88	227.10	227.14	229.72
SD	11.92	10.55	10.47	9.5	9.75	9.09	9.76	9.36	10.44	10.32
Pct	59	59	61	61	64	65	67	67	67	69
Conditional Percentile Rank										
10	194	201	202	207	207	212	211	215	214	216
15	197	204	204	210	210	214	214	217	216	219
20	199	206	206	212	212	216	216	219	218	221
25	201	208	208	213	213	218	217	221	220	223
30	203	209	209	215	215	219	219	222	222	224
35	205	211	211	216	216	220	220	223	223	226
40	206	212	212	217	217	221	221	225	224	227
45	208	213	214	218	219	223	223	226	226	228
50	209	215	215	220	220	224	224	227	227	230
55	211	216	216	221	221	225	225	228	228	231
60	212	217	218	222	222	226	226	229	230	232
65	214	219	219	223	224	227	228	231	231	234
70	216	220	220	225	225	228	229	232	233	235
75	217	222	222	226	226	230	230	233	234	237
80	219	224	224	228	228	231	232	235	236	238
85	222	226	226	229	230	233	234	237	238	240
90	225	228	228	232	232	235	236	239	241	243

Note: Pct = Percentile

Table 9: Predicted Benchmark for MAP Reading by Grade/Term and Percentile Ranks for HS Seniors Expected to Meet the Reading ACT=24 Benchmark

	Grade	5		6		7		8		9	
	Term	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
	Benchmark	212.62	217.94	218.32	222.87	223.21	227.04	227.31	230.46	230.61	233.11
	SD	11.95	10.53	10.49	9.50	9.76	9.08	9.77	9.35	10.45	10.32
	Pct	69	66	68	69	71	72	73	74	75	75
Conditional Percentile Rank	10	197	204	205	211	211	215	215	218	217	220
	15	200	207	207	213	213	218	217	221	220	222
	20	203	209	209	215	215	219	219	223	222	224
	25	205	211	211	216	217	221	221	224	224	226
	30	206	212	213	218	218	222	222	226	225	228
	35	208	214	214	219	219	224	224	227	227	229
	40	210	215	216	220	221	225	225	228	228	230
	45	211	217	217	222	222	226	226	229	229	232
	50	213	218	218	223	223	227	227	230	231	233
	55	214	219	220	224	224	228	229	232	232	234
	60	216	221	221	225	226	229	230	233	233	236
	65	217	222	222	227	227	231	231	234	235	237
	70	219	223	224	228	228	232	232	235	236	239
	75	221	225	225	229	230	233	234	237	238	240
	80	223	227	227	231	231	235	236	238	239	242
	85	225	229	229	233	233	236	237	240	241	244
	90	228	231	232	235	236	239	240	242	244	246

Note: Pct = Percentile

Table 10: Predicted Probability of an Observed MAP Mathematics Score Meeting or Exceeding Selected MAP Benchmarks by Grade/Term for HS Seniors Expected to Meet the Mathematics ACT=22 Benchmark

	Grade	5		6		7		8		9	
	Term	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
	Benchmark	217.31	225.58	225.30	232.34	232.20	238.06	238.00	242.73	242.72	246.35
	SD	11.46	10.38	10.01	9.59	9.41	9.40	9.61	9.87	10.53	10.99
	Pct	65	61	68	66	71	70	74	74	76	74
Observed Score	210	1	1	1	1	1	1	1	1	1	1
	212	5	1	1	1	1	1	1	1	1	1
	214	15	1	1	1	1	1	1	1	1	1
	216	34	1	1	1	1	1	1	1	1	1
	218	59	1	1	1	1	1	1	1	1	1
	220	80	4	5	1	1	1	1	1	1	1
	222	93	13	15	1	1	1	1	1	1	1
	224	98	31	34	1	1	1	1	1	1	1
	226	99	55	59	2	3	1	1	1	1	1
	228	99	78	80	9	9	1	1	1	1	1
	230	99	92	93	23	25	1	1	1	1	1
	232	99	98	98	46	48	3	3	1	1	1
	234	99	99	99	70	71	11	11	1	1	1
	236	99	99	99	87	88	27	27	2	2	1
	238	99	99	99	96	97	50	50	7	7	1
	240	99	99	99	99	99	73	73	20	20	2
	242	99	99	99	99	99	89	89	41	41	9
	244	99	99	99	99	99	97	97	65	66	23
	246	99	99	99	99	99	99	99	85	85	46
	248	99	99	99	99	99	99	99	95	95	70
	250	99	99	99	99	99	99	99	99	99	87
	252	99	99	99	99	99	99	99	99	99	96
	254	99	99	99	99	99	99	99	99	99	99
	256	99	99	99	99	99	99	99	99	99	99

Note: SEM = 3.2; Pct = Percentile

Table 11: Predicted Probability of an Observed MAP Mathematics Score Meeting or Exceeding Selected MAP Benchmarks by Grade/Term for HS Seniors Expected to Meet the Mathematics ACT=24 Benchmark

Grade	5		6		7		8		9	
Term	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Benchmark	221.33	229.74	229.63	236.82	236.84	242.85	242.96	247.83	247.99	251.76
SD	11.58	10.49	10.16	9.73	9.59	9.57	9.83	10.07	10.78	11.23
Pct	74	70	79	76	81	79	83	81	84	83
Observed Score										
214	1	1	1	1	1	1	1	1	1	1
216	5	1	1	1	1	1	1	1	1	1
218	15	1	1	1	1	1	1	1	1	1
220	34	1	1	1	1	1	1	1	1	1
222	58	1	1	1	1	1	1	1	1	1
224	80	4	4	1	1	1	1	1	1	1
226	93	12	13	1	1	1	1	1	1	1
228	98	29	31	1	1	1	1	1	1	1
230	99	53	55	2	2	1	1	1	1	1
232	99	76	77	7	7	1	1	1	1	1
234	99	91	91	19	19	1	1	1	1	1
236	99	97	98	40	40	2	1	1	1	1
238	99	99	99	64	64	6	6	1	1	1
240	99	99	99	84	84	19	18	1	1	1
242	99	99	99	95	95	39	38	3	3	1
244	99	99	99	99	99	64	63	12	11	1
246	99	99	99	99	99	84	83	28	27	4
248	99	99	99	99	99	95	94	52	50	12
250	99	99	99	99	99	99	99	75	74	29
252	99	99	99	99	99	99	99	90	90	53
254	99	99	99	99	99	99	99	97	97	76
256	99	99	99	99	99	99	99	99	99	91
258	99	99	99	99	99	99	99	99	99	97
260	99	99	99	99	99	99	99	99	99	99

Note: SEM = 3.2; Pct = Percentile

Table 12: Predicted Probability of an Observed MAP Reading Score Meeting or Exceeding Selected MAP Benchmarks by Grade/Term for HS Seniors Expected to Meet the Reading ACT=22 Benchmark

Grade	5		6		7		8		9	
Term	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Benchmark	209.31	214.70	214.97	219.59	219.83	223.73	223.88	227.10	227.14	229.72
SD	11.92	10.55	10.47	9.50	9.75	9.09	9.76	9.36	10.44	10.32
Pct	59	59	61	61	64	65	67	67	67	69
Observed Score										
200	1	1	1	1	1	1	1	1	1	1
202	2	1	1	1	1	1	1	1	1	1
204	6	1	1	1	1	1	1	1	1	1
206	17	1	1	1	1	1	1	1	1	1
208	35	2	2	1	1	1	1	1	1	1
210	58	8	7	1	1	1	1	1	1	1
212	79	21	19	1	1	1	1	1	1	1
214	92	42	39	5	4	1	1	1	1	1
216	98	65	62	15	13	1	1	1	1	1
218	99	83	81	32	30	5	4	1	1	1
220	99	94	93	55	52	14	13	2	2	1
222	99	98	98	76	74	31	29	7	7	1
224	99	99	99	90	89	53	51	18	18	5
226	99	99	99	97	97	75	73	37	37	14
228	99	99	99	99	99	90	89	60	60	31
230	99	99	99	99	99	97	96	80	80	53
232	99	99	99	99	99	99	99	93	92	75
234	99	99	99	99	99	99	99	98	98	90
236	99	99	99	99	99	99	99	99	99	97
238	99	99	99	99	99	99	99	99	99	99

Note: SEM = 3.4; Pct = Percentile

Table 13: Predicted Probability of an Observed MAP Reading Score Meeting or Exceeding Selected MAP Benchmarks by Grade/Term for HS Seniors Expected to Meet the Reading ACT=24 Benchmark

Grade	5		6		7		8		9	
Term	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall	Spring
Benchmark	212.62	217.94	218.32	222.87	223.21	227.04	227.31	230.46	230.61	233.11
SD	11.95	10.53	10.49	9.50	9.76	9.08	9.77	9.35	10.45	10.32
Pct	69	66	68	69	71	72	73	74	75	75
Observed Score										
204	1	1	1	1	1	1	1	1	1	1
206	3	1	1	1	1	1	1	1	1	1
208	9	1	1	1	1	1	1	1	1	1
210	22	1	1	1	1	1	1	1	1	1
212	43	4	3	1	1	1	1	1	1	1
214	66	12	10	1	1	1	1	1	1	1
216	84	28	25	2	2	1	1	1	1	1
218	94	51	46	8	6	1	1	1	1	1
220	99	73	69	20	17	2	2	1	1	1
222	99	88	86	40	36	7	6	1	1	1
224	99	96	95	63	59	19	16	3	3	1
226	99	99	99	82	79	38	35	10	9	2
228	99	99	99	93	92	61	58	24	22	7
230	99	99	99	98	98	81	79	45	43	18
232	99	99	99	99	99	93	92	68	66	37
234	99	99	99	99	99	98	98	85	84	60
236	99	99	99	99	99	99	99	95	94	80
238	99	99	99	99	99	99	99	99	99	92
240	99	99	99	99	99	99	99	99	99	98
242	99	99	99	99	99	99	99	99	99	99

Note: SEM = 3.4; Pct = Percentile