Algebra I Keystone Exam Proficiency and Growth

A specific cohort of Algebra I students from State College Area High School in State College, Pennsylvania, participated in a pilot implementation of Get More Math beginning in the 2016–2017 school year. This Algebra I course saw a significant improvement in student proficiency and growth measures on the Pennsylvania Keystone Algebra Exam. Students also exceeded expectations for the likelihood of passing the Keystone Exam as predicted by the Pennsylvania Value-Added Assessment System (PVAAS).

Introduction

Mathematics teaching and learning has come under scrutiny in the last several years, particularly in the United States. On the 2018 PISA, students from the United States ranked 37th out of 78 educational systems assessed in mathematics (Schleicher, 2019, p. 7). Educational experts have long debated the merits and challenges of conceptual versus procedural understanding, individualized instruction, and how students learn best. Two evidence-based strategies that address long-term retention and student learning are retrieval practice and differentiation.

Retrieval practice is simply recall of knowledge over time, which reinforces learning by pulling information out of the brain rather than trying to improve retention by relistening, rereading, or reobserving. For mathematics in particular, Kim et al. (2013) posited that mastering cognitive skills benefits from distributed practice (p. 31). When retrieval practice is interleaved, spaced, and varied, learners mimic how we experience life, which makes our memory stronger (Brown et al., 2014, p. 66). Brown et al. (2014) further explained our misunderstanding of massed practice—most people insist that repetitively practicing a concept with a singular focus will help us to master it (p. 47). However, research in cognitive science does not support this idea. While educators often perceive distributed retrieval practice as an assessment tool, it functions as a learning tool that produces “desirable difficulty during learning” (Roediger & Karpicke, 2006, p. 254).

While incorporating appropriate retrieval practice and other learning strategies is possible without technology, there are ways that computers can address complex issues and analyses that are beyond the capacity of most teachers. Get More Math is a program that provides adaptive, individualized,

cumulative practice for mathematics students to increase long-term retention. Get More Math leverages research-based retrieval practice using spacing and interleaving. The software determines which skill a student should attempt founded on data about the student's strengths, weaknesses, and time since last practicing each skill.

Another way Get More Math addresses complex student needs is through content differentiation. Get More Math is not an instructional tool, so it allows the teacher to deliver the appropriate instruction for students while the software dynamically provides practice problems that are tailored to each student's needs. The program intelligently selects problems for a student from a set of teacher-assigned skills based on each student's past successes and failures. These problem choices deliver "the value of differentiation to respond to student readiness… from the opportunities for all students to work with tasks that challenge them" (Little, 2009, p. 42). Get More Math also scaffolds individual skills to meet students at the appropriate level. This multi-level approach to individualization of practice keeps students in their zone of proximal development, which is integral in making learning efficient and effective (Murray, 2002, p. 749).

Get More Math was created by a mathematics teacher in the early 2000's and refined for over a decade in the classroom before being released to a set of pilot schools in Pennsylvania. This document will discuss the results that one of those schools experienced while implementing Get More Math.

School Profile

State College Area High School is a public high school located in State College, Pennsylvania, the home of Penn State University. The town of State College has a population of approximately 40,000 people (United States Census Bureau, 2022). According to the National Center for Education Statistics, State College Area High School had an enrollment of 2,356 students in the 2019–2020 school year (NCES, 2021). Of those students, approximately 20% were minority or two or more races. The high school is a Title I school with about 18% of the student body being economically disadvantaged and receiving free or reduced-price lunches.

Implementation

State College Area High School (SCAHS) is considered an academically successful high school by most metrics. Their 2017 SAT scores ranked 23rd out of 650 schools in Pennsylvania (State College Area High School, 2022). In 2021, 564 students took 1,024 Advanced Placement exams, and 83% of those exam scores were three or higher, the typical accepted threshold for college credit (SCAHS, 2022). The high school also experienced a 92.5% graduation rate (SCAHS, 2022).

However, students in State College's elective College Prep Algebra I A/B (CPA1AB) course rarely attained proficiency on the state-mandated Keystone Algebra I Exam. Students are rated below basic, basic, proficient, or advanced. From 2013 to 2016, in the four years prior to implementing Get More Math, only 12 out of over 300 students in the CPA1AB course at State College achieved a rating of proficient, and not one was considered advanced. Stakeholders implemented Get More Math in the

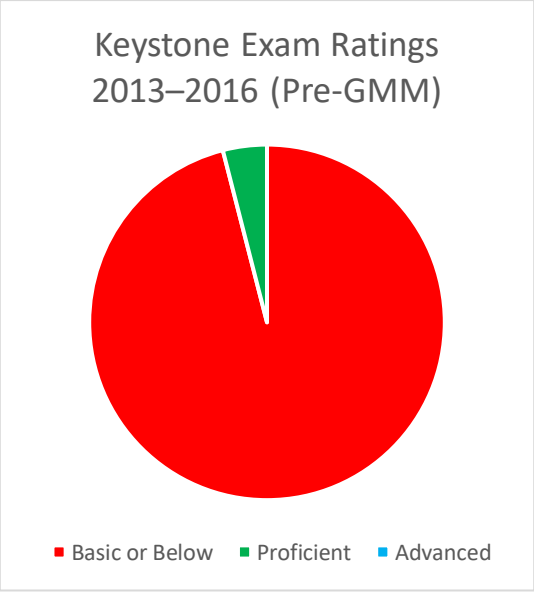
2016–2017 school year to improve student long-term retention with the hope that this would in turn improve Keystone Exam results.

It is important to note a few other conditions under which the pilot was conducted. Prior to using Get More Math and throughout its implementation, all students enrolled in CPA1AB were one-to-one with computing devices. The course has always been co-taught with two certified teachers; in Fall of 2016 SCAHS moved from using a certified learning support teacher as the second teacher to using a certified math teacher as the second teacher. A total of four different mathematics teachers co-taught different sections of CPA1AB in the pilot years discussed in this study. The class met 90 minutes per day, every other day, prior to implementing Get More Math and for the first year of usage. Beginning in 2017-2018, the class met 90 minutes per day, every day. Enrollment in the course dropped a bit after it started to meet daily, likely because it was an elective course that required more time from a student's schedule.

Results

Part 1: Proficiency

The results from implementing Get More Math were profoundly evident after the first round of state standardized tests in 2017. **Out of 103 students, 33 achieved a rating of proficient or better on the Keystone Algebra Exam—almost three times more than the prior four years combined.** No students had ever achieved a level of advanced from this course before, but three students were advanced on the 2017 exam. The following year, on the 2018 exam, out of 91 students in the Algebra course, 28 were proficient and 11 were advanced. In 2019, out of 79 students in the course, 25 students were proficient and 7 were advanced. In those first three years of using Get More Math, a total of 104 students out of 273, or 38.1%, achieved a rating of at least proficient on the Keystone Algebra I Exam—approximately nine times the passing rate of the years preceding Get More Math implementation.



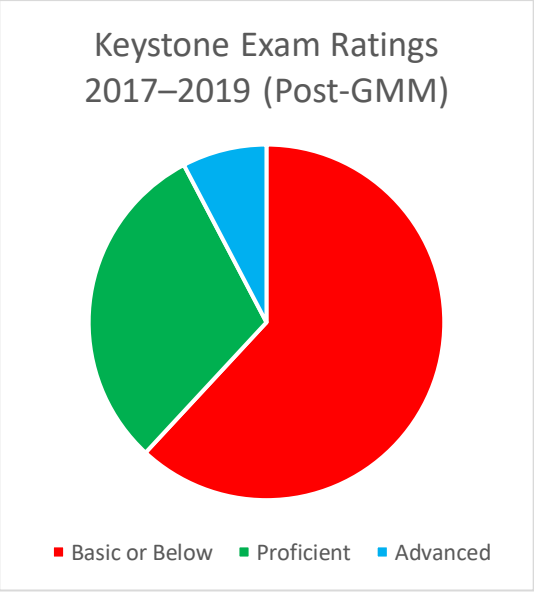


Figure 1: Keystone Exam Proficiency, SCAHS CPA1AB, 2013–2019

The Keystone Exam pass rate of 38.1% in the first three years of utilizing Get More Math shows a statistically significant increase ($p < 0.0001$, see Appendix C) when compared to the Keystone pass rate of 4% (based on 12 out of 300) in the four years prior to the implementation of Get More Math.

Part 2: Predicted Scores

Pennsylvania uses the Pennsylvania Value-Added Assessment System, or PVAAS, to measure growth and make predictions about student scores. According to the Pennsylvania Department of Education, non-partisan researchers have called the PVAAS approach one of the most reliable approaches in measuring student growth (Pennsylvania Department of Education, 2021a). To determine an estimated likelihood of passing the Algebra I Keystone Exam, the PVAAS model uses all appropriate available prior state assessment scores for an individual and then creates a predicted score based on the profile of all students who had similar previous scores (Pennsylvania Department of Education, 2021b). The state calculates the probability of a student scoring greater than or equal to the cut score for proficiency based on the predicted score and the associated standard error for that student profile.

For the 2017 test, the first year utilizing Get More Math, 90 of the 103 students had data from PVAAS predicting their chances of passing the Keystone Exam (see Appendix A). The mean predicted probability of scoring proficient or better was 22.2%. However, it is important to note that the data were notably skewed right, and the median prediction was a 10.85% probability of passing. However, 33 out of 90, or 36.7% of those students passed.

In Figure 2 below, the 2017 Keystone Exam scores for CPA1AB are plotted against each student's percentage likelihood of passing, along with an inverse normal cumulative density function using a mean of 1,500 and the 2017 Spring Keystone Algebra I standard deviation of 56.6 (Data Recognition Corporation, 2017). The vertical distance of student data points from the curve indicates an actual performance greater than the predicted score for approximately 85% of the students with PVAAS predictions.

Results were even better for the 2018 Keystone Algebra I Exam. In 2018, the mean predicted pass rate was 15% with a median of 7% for the 72 students with PVAAS data. However, 50% of the students scored proficient or better. Figure 3 below shows Keystone Exam scores plotted against each student's percentage likelihood of passing, again with an inverse normal density function with a mean of 1500 and the 2018 Spring Keystone Algebra I standard deviation of 56.6 (Data Recognition Corporation, 2018). Approximately 95% of these student exceeded their PVAAS expectations.

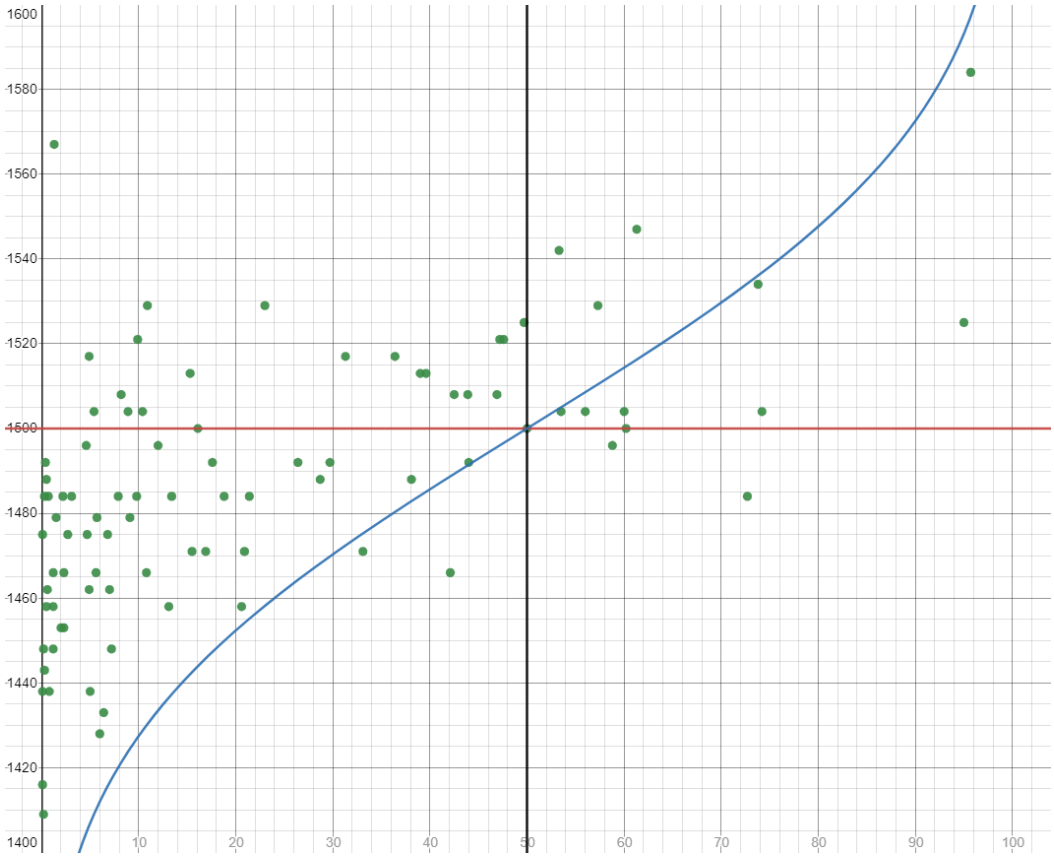


Figure 2: Keystone Exam Algebra Score vs. Likelihood of Passing, SCAHS CPA1AB, 2017

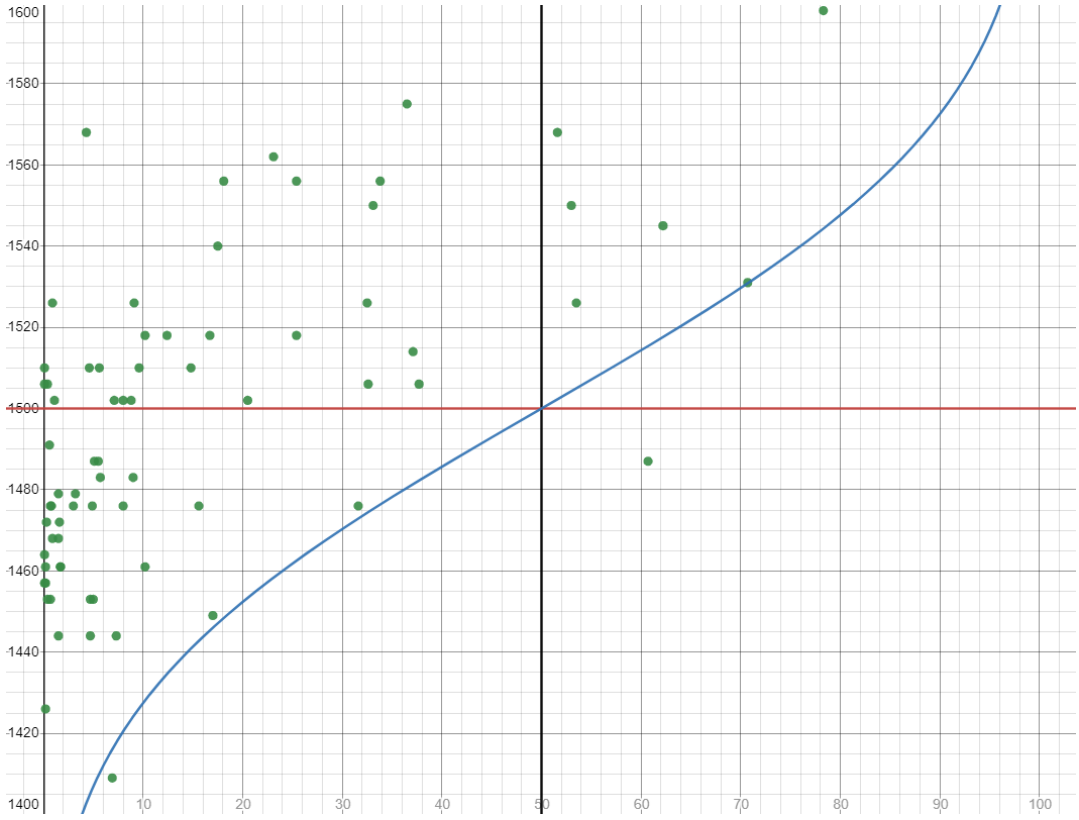


Figure 3: Keystone Exam Algebra Score vs. Likelihood of Passing, SCAHS CPA1AB, 2018

Results were similar in 2019, when the mean and median percentages for likelihood of passing were 11.35% and 3.5%, respectively. Yet on the 2019 Keystone exam, 35.7% of the test-takers with PVAAS data were proficient or better.

Part 3: Growth

The PVAAS system also aggregates all the growth data for a set of students into a growth measurement that can be representative of a teacher, a school, or an entire district. The average growth index is a measurement of how many standard errors away from a growth measure of zero a set of students has scored (Pennsylvania Department of Education, 2021b, p. 20). Thus, scores between negative one and one are considered to have met the growth standard, as they are within one standard error of zero, showing evidence of no difference between the actual achievement and the expected achievement. Average growth indices greater than two would be considered exceptionally good, as they are greater than two standard errors from a growth measure of zero.

In the year before implementing Get More Math, State College Area High School already had an average growth index of 14.95, bolstered by the higher-level Algebra I classes that were already achieving widespread success on the Keystone Exams. After implementing Get More Math in CPA1AB, the high school saw its average growth index climb to incredible values around 20.

Year	2016 (pre-GMM)	2017	2018	2019
Growth Index	14.95	18.8	20.24	20.72

Table 1: PVAAS Average Growth Index, SCAHS, 2016–2019

Out of 1,096 schools with PVAAS growth data, SCAHS ranked second in the state of Pennsylvania for their three-year average from 2017 to 2019, their first three years of implementing Get More Math (SAS Institute, Inc., 2022). In 2018, they were ranked first in the state (see Appendix B). A one-sample t-test confirms with statistical significance ($p < 0.01$, see Appendix C) that State College's average growth index in the first three years of using Get More Math has a mean value greater than 15. These scores were strengthened by the growth indices for the students in the course utilizing Get More Math, which are shown in the table below.

Year	2017	2018	2019
CPA1AB Growth Index	27.8	29.1	24.35

Table 2: PVAAS Average Growth Index, Algebra I Class with GMM, 2017–2019

Conclusion

Upon seeing the need for a different approach for students in an Algebra I course at State College Area High School, teachers and stakeholders implemented Get More Math to focus on long-term retention and to improve student proficiency on year-end standardized tests. The use of Get More Math led to notable improvements in student proficiency and growth, and State College continues to use Get More Math with success.

Appendix A: Keystone Exam Algebra Score vs. Likelihood of Passing, SCAHS CPA1AB

2017 Keystone Results with GMM for Students with PVAAS Data

Likelihood of Proficiency (%)	2017 Keystone Algebra I Score
95.7	1584
95	1525
74.2	1504
73.8	1534
72.7	1484
61.3	1547
60.2	1500
60	1504
58.8	1496
57.3	1529
56	1504
53.5	1504
53.3	1542
50	1500
49.7	1525
47.6	1521
47.2	1521
46.9	1508
44	1492
43.9	1508
42.5	1508
42.1	1466
39.6	1513
39	1513
38.1	1488
36.4	1517
33.1	1471
31.3	1517
29.7	1492
28.7	1488
26.4	1492
23	1529
21.4	1484
20.9	1471
20.6	1458
18.8	1484
17.6	1492
16.9	1471
16.1	1500
15.5	1471
15.3	1513
13.4	1484
13.1	1458
12	1496
10.9	1529
10.8	1466
10.4	1504
9.9	1521
9.8	1484
9.1	1479
8.9	1504
8.2	1508
7.9	1484
7.2	1448
7	1462
6.8	1475
6.4	1433
6	1428
5.7	1479
5.6	1466
5	1438
4.9	1517
4.9	1462
4.7	1475
4.6	1496
3.1	1484
2.3	1466
2.3	1453
2.2	1484
2	1453
1.5	1479
1.3	1567
1.2	1466
1.2	1458
1.2	1448
0.8	1438
0.7	1484
0.6	1462
0.5	1488
0.5	1458
0.4	1492
0.3	1484
0.3	1443
0.2	1448
0.2	1409
0.1	1475
0.1	1438
0.1	1416

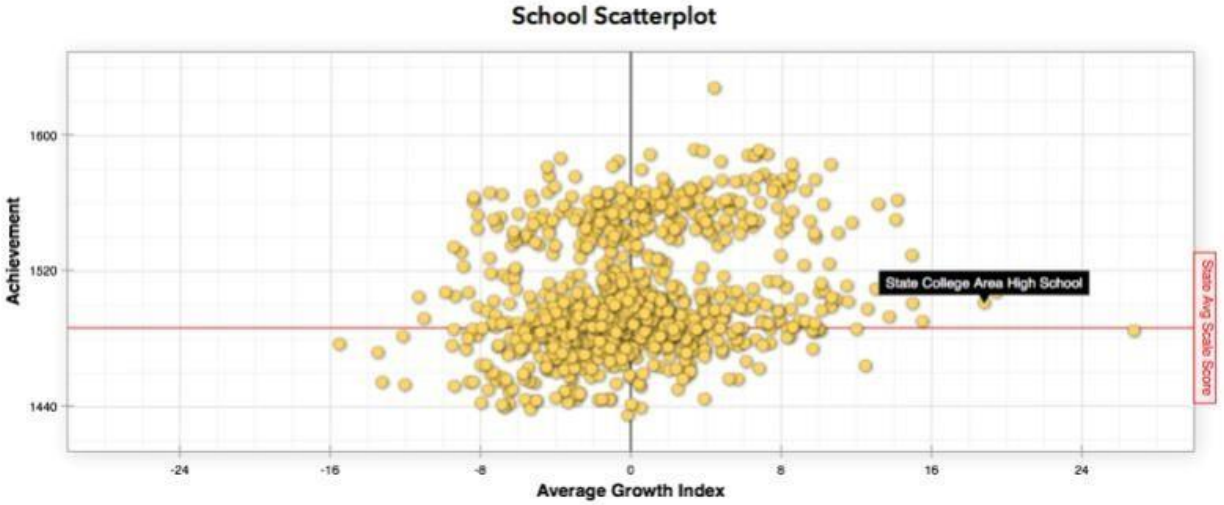
2018 Keystone Results with GMM for Students with PVAAS Data

Likelihood of Proficiency (%)	2018 Keystone Algebra I Score
78.3	1598
70.7	1531
62.2	1545
60.7	1487
53.5	1526
53	1550
51.6	1568
37.7	1506
37.1	1514
36.5	1575
33.8	1556
33.1	1550
32.6	1506
32.5	1526
31.6	1476
25.4	1518
25.4	1556
23.1	1562
20.5	1502
18.1	1556
17.5	1540
17	1449
16.7	1518
15.6	1476
14.8	1510
12.4	1518
10.2	1461
10.2	1518
9.6	1510
9.1	1526
9	1483
8.8	1502
8	1476
8	1502
7.3	1444
7.1	1502
6.9	1409
5.7	1483
5.6	1510
5.5	1487
5.1	1487
5	1453
4.9	1476
4.7	1444
4.7	1453
4.6	1510
4.3	1568
3.2	1479
3	1476
1.7	1461
1.7	1461
1.6	1472
1.5	1444
1.5	1468
1.5	1479
1.1	1502
0.9	1468
0.9	1526
0.8	1476
0.7	1453
0.7	1476
0.6	1491
0.4	1453
0.4	1506
0.3	1472
0.2	1426
0.2	1457
0.2	1461
0.1	1457
0.1	1464
0.1	1506
0.1	1510

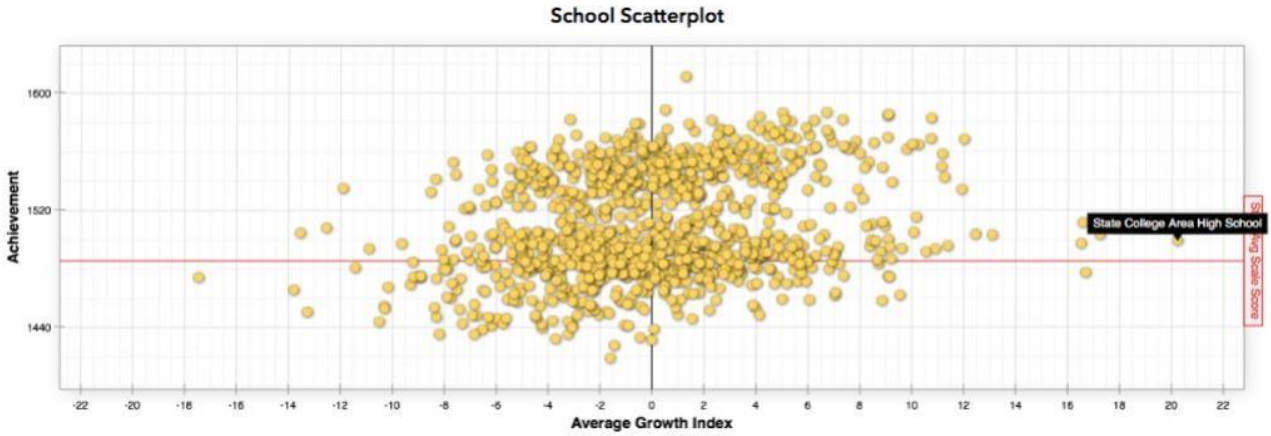
2019 Keystone Results with GMM for Students with PVAAS Data
(Note: Specific scores were not available at the time of publication.)

Likelihood of Proficiency (%)	2019 Keystone Algebra I Proficiency
60	Proficient
58.8	Advanced
44.9	Proficient
43.5	Proficient
40.2	Advanced
28.6	Proficient
28.2	Advanced
26.6	Advanced
24.1	Advanced
16	Basic
12.8	Basic
11.6	Basic
9.4	Advanced
8.9	Basic
7.2	Proficient
5.7	Basic
5.6	Basic
5.5	Proficient
4.6	Proficient
4.2	Basic
3.8	Basic
3.2	Basic
3.1	Basic
3.1	Basic
3	Basic
2.9	Below Basic
2.4	Basic
2.1	Basic
1.4	Basic
1.2	Proficient
0.8	Below Basic
0.6	Basic
0.5	Basic
0.5	Proficient
0.4	Basic
0.4	Below Basic
0.3	Below Basic
0.2	Basic
0.2	Basic
0.1	Basic
0.1	Basic
0.1	Basic

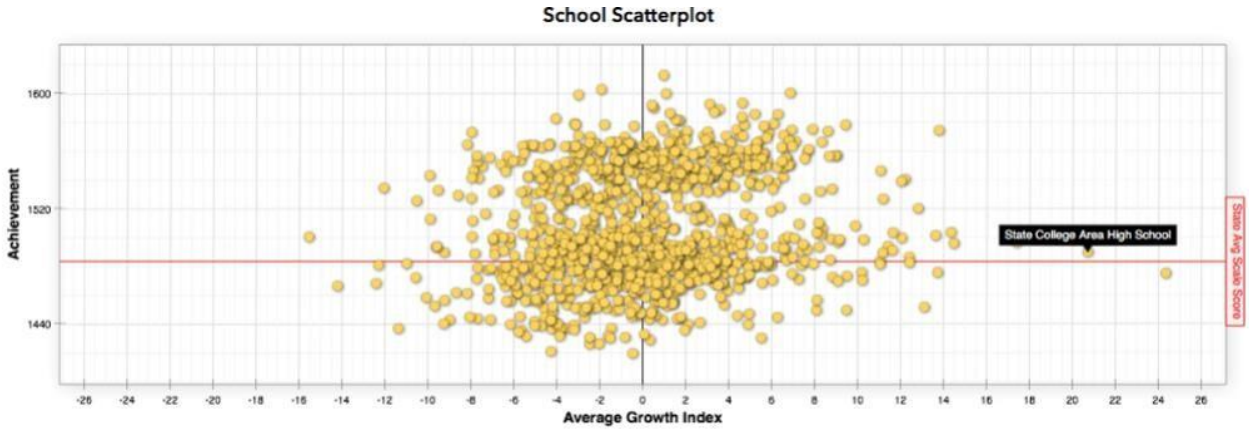
Appendix B: PVAAS Achievement vs. Average Growth Scatterplots, 2017–2019



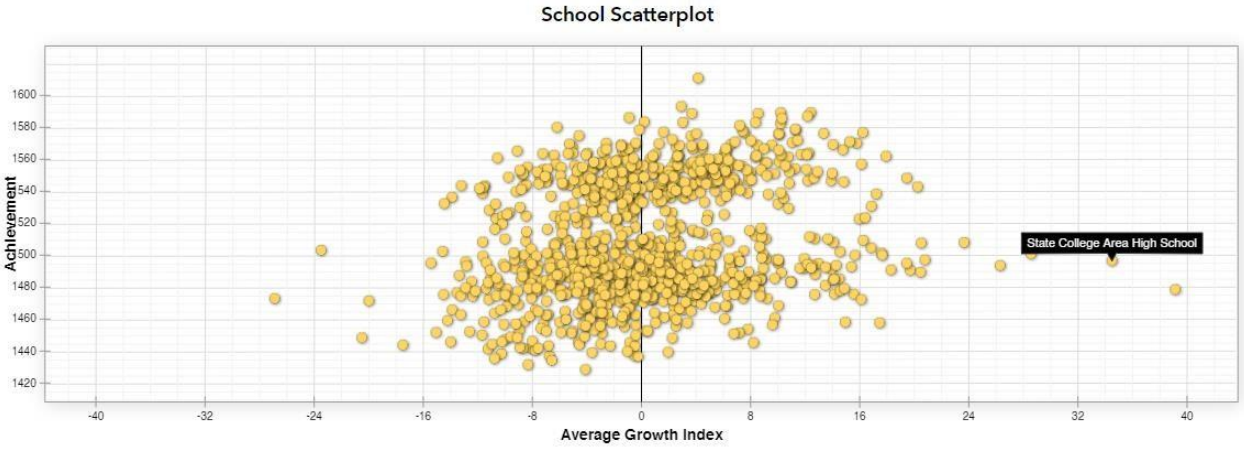
2017 Achievement vs. Average Growth Index



2018 Achievement vs. Average Growth Index



2019 Achievement vs. Average Growth Index



2017–2019 Achievement vs. Average Growth Index (Note: The Average Growth Index for this measure is not simply the average of the three years; PVAAS recalculates the value based on the standard error of the mean for the data set.)

Appendix C: Hypothesis Tests

Proportion of Students Proficient Before and After Get More Math Implementation

Two sample proportion summary hypothesis test:

p_1: proportion of successes for population 1 (2017–2019)
p_2: proportion of successes for population 2 (2013–2016)
$p_1 - p_2$: Difference in proportions
H_0: $p_1 - p_2 = 0$
H_A: $p_1 - p_2 > 0$

Hypothesis test results:

Difference	Count1	Total1	Count2	Total2	Sample Diff.	Std. Err.	Z-Stat	P-value
$p_1 - p_2$	104	273	12	300	0.34095238	0.033609947	10.144389	<0.0001

Mean of Average Growth Index for State College Area High School, 2017–2019

One sample T hypothesis test:

μ: Mean of variable
H_0: μ = 15
H_A: μ > 15

Hypothesis test results:

Variable	Sample Mean	Std. Err.	DF	T-Stat	P-value
var1	19.92	0.5768882	2	8.5285155	0.0067

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