getmoremath!

CASE STUDY:

LAMPETER-STRASBURG HIGH SCHOOL (PA)

Exceeding Predictions on the Algebra 1 Keystone Exam

In the early 2000s, a teacher in Lampeter-Strasburg High School in Pennsylvania developed the software Get More Math to improve long-term retention of mathematics through adaptive, individualized mixed review. The refinement of this software in the classroom coincided with the development and release of the Keystone Exams, which were intended to measure student growth and mastery of core subjects. The first testing year for the Keystone Algebra I Exams was the 2012-2013 school year. Students using Get More Math in the Lampeter-Strasburg teacher's classroom surpassed the expectations for likelihood of passing the Keystone Exam as predicted by the Pennsylvania Value-Added Assessment System.

- *From 2013 to 2016, 248 out of 265, or 93.6%, of the students using Get More Math in this classroom exceeded their predicted score on the Keystone Exam.*
- *Of the 265 students who took the Keystone Exam, only 123 were predicted to pass. However, with Get More Math, 214 of those students attained a passing score—73% more than expected.*
- *The mean score on the Keystone Exam of the students using Get More Math was 1534, which was a statistically significant ($p < 0.0001$) average improvement of 38 points over the mean predicted score of 1496.*
- *The growth in score from a predicted value of 1496 to an actual value of 1534 leads to a Cohen's d effect size of 0.98, which is considered a large effect size.*

In addition, the average growth index for the teacher using Get More Math far exceeded the norm.

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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 re-listening, rereading, or re-observing. 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 single 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, providing each student with a differentiated experience. Little et al. (2009) explained, "the value of differentiation [is] to respond to student readiness… [and provide] opportunities for all students to work with tasks that challenge them" (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. Murray and Arroyo discussed accessing a student's zone of proximal development as integral in making learning efficient and effective (p. 749).

Get More Math was created by a mathematics teacher in the early 2000's and was 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 the first school using Get More Math experienced when the creator of the software implemented it in his classroom.

School Profile

Lampeter-Strasburg School District is in central Lancaster County in Pennsylvania, serving the townships of Lampeter and Strasburg and the historic borough of Strasburg. For the years discussed in this study, L-S High School graduated about 250 students per year. According to recent data from the National Center for Education Statistics, the high school had an enrollment of 972 students in the 2020-2021 school year (NCES, 2022). Of those students, approximately 17% were minority or two or more races. The high school is a Title I school with about 21% of the student body being economically disadvantaged and receiving free or reduced-price lunches.

Implementation

The creator of Get More Math began teaching high school math in 1996. Beginning with his first year, he experimented with strategies to improve long-term retention. He built the first version of Get More Math software in 2004 and continued to refine it in his classroom through 2016.

In the 2012–2013 school year, the Keystone Algebra I Exam was mandated by the state of Pennsylvania for all students as an end-of-course assessment upon completing Algebra I. That, along with the existing Pennsylvania Value-Added Assessment System (PVAAS) used to measure student growth, provided a robust environment in which to measure the growth and achievement of the students using Get More Math software.

Get More Math was utilized in two different levels of Algebra I for ninth grade students; most students took the course for a full year of block scheduling, while about 20% took it for one semester of block scheduling. For this document, those students are not disaggregated into subgroups. However, the results of this study show significant growth across different ability levels, which are typically demarcated by predicted scores generated by the PVAAS model. The data from the Algebra I classes discussed in the study span the Keystone Exam testing years from 2013 to 2016.

Results

The results of using Get More Math were significant for student growth. To measure growth, Pennsylvania uses the Pennsylvania Value-Added Assessment System, or PVAAS, to 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). In order 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.

The first notable measure of growth for L-S students was in the number of students who were predicted to pass the Keystone Algebra I Exam versus the number of students who passed (see Figure 1). From 2013 to 2016, only 123 out of 265 students using Get More Math with this teacher were predicted to pass, or fewer than half. However, 214 ended up passing the exam—over 80%, which is notably higher than the typical Pennsylvania pass rate of 60% to 70%.

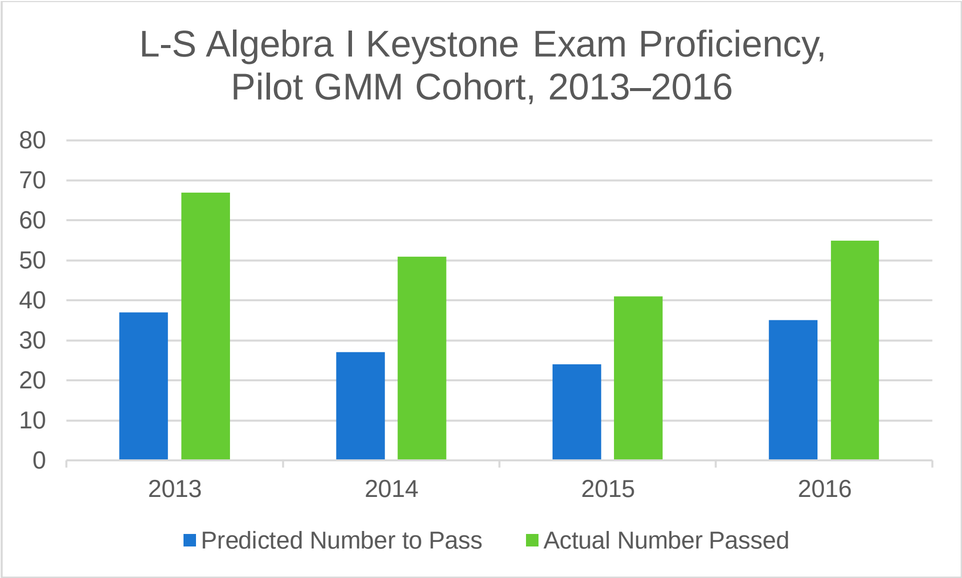


Figure 1: Keystone Exam Proficiency, L-S Algebra I Pilot GMM Cohort, 2013-2016

While not all students attained a rating of proficient or advanced, most of the students who did not still showed growth. Of the 265 students in the 2013 to 2016 study, 248 students scored better than they were predicted to score, an astounding 94%.

In Figure 2 below, the results of the 2016 PVAAS data are displayed for each individual student (for raw data, see Appendix A). Predicted results are shown by red and blue bars, while actual results are shown by the additional green bars, except for the two students who scored lower than predicted. Bold horizontal lines indicate the threshold ratings of Basic, Proficient (1500—the minimum passing score), and Advanced.

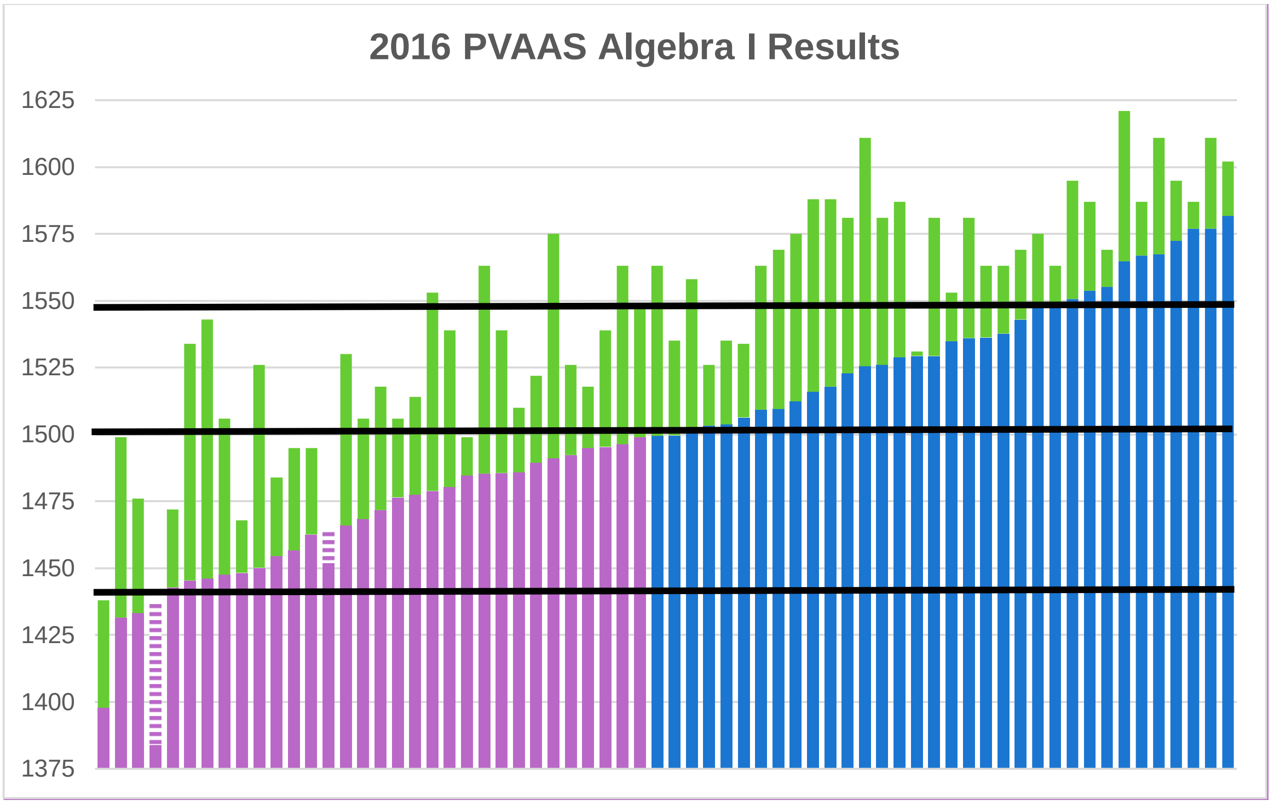


Figure 2: Keystone Algebra I Exam Predicted & Actual Scores, L-S Algebra I, 2016 (see Appendix B for 2013–2015 graphics)

From 2013 to 2016, the average predicted score for students in these Algebra I classes was 1495.9. The average actual score for those students was 1534.2. This is a statistically significant improvement ($p < 0.0001$, see Appendix C) of 38.3 points over the predicted average. Using Cohen's *d*, with pooled standard deviation, the effect size of this average score increase is 0.98 (see Appendix C), which meets the criteria for a large effect size.

The growth in scores for this L-S teacher utilizing Get More Math was not exclusive to low-achieving students. The scatterplot in Figure 3 plots the predicted scores vs. the actual scores for the 265 students in this study. The line of best fit is also plotted with these points ($r = 0.795$). The slope of 0.96, slightly less than 1, for the line of best fit, indicates that growth was consistent across all levels of achievement, with an inclination towards increased growth for low-achieving students. The line $y = x$ is also plotted on the graph to show the expected line of best fit when the actual score matches the predicted score for each student.

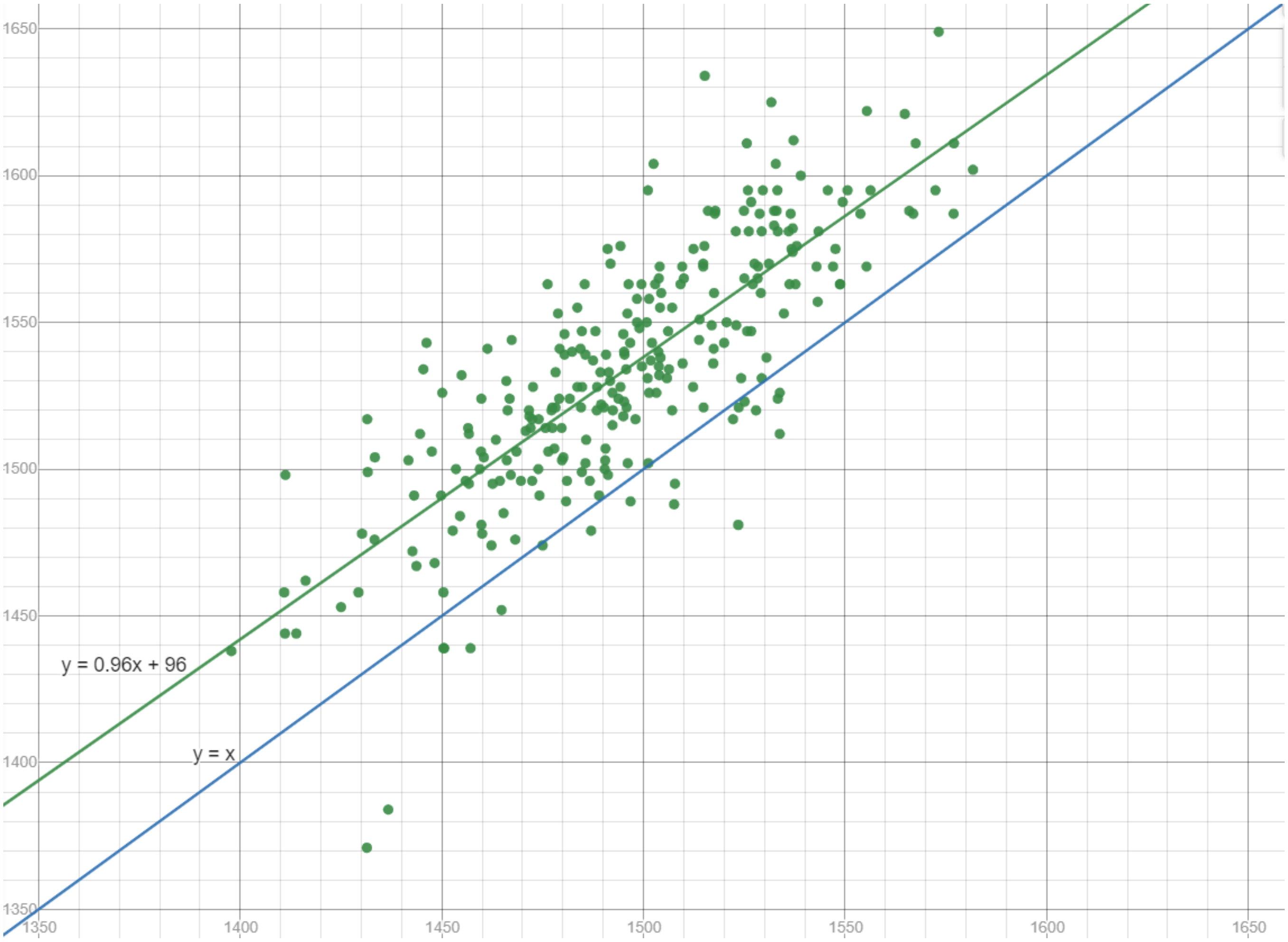


Figure 3: Predicted Score vs. Actual Score Scatterplot, L-S Algebra I, 2013-2016

The Pennsylvania Value-Added Assessment System distills growth measures down to one number, the average growth index, which can be compared across schools and districts. The growth index is also rolled into a three-year composite score. For this L-S classroom, the three-year composite growth index was 16.41 for 2014 to 2016. This is not an average of those three years but a compilation of the data across those three years. The growth index of each individual year for this teacher from 2014 to 2016 is shown below in Figure 4; over this time period the indices hovered between 7 and 13.

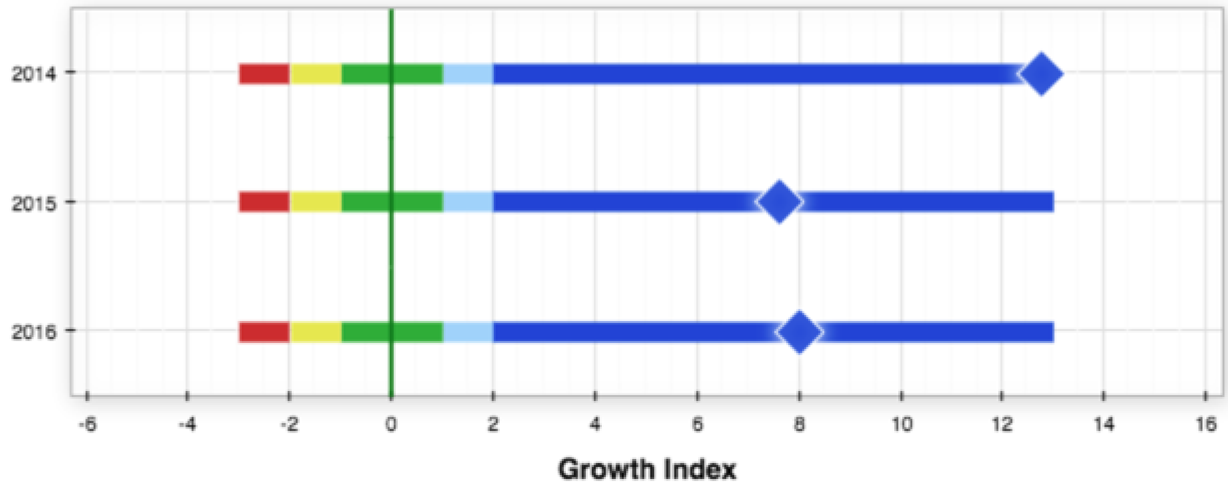


Figure 4: PVAAS Average Growth Index, L-S Algebra I, 2014-2016

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 are considered exceptionally good, as they are greater than two standard errors from a growth measure of zero.

Conclusion

The impetus behind Get More Math was one teacher's recognition that traditional math teaching techniques did not maximize his students' long-term retention. By utilizing technology and implementing Get More Math software, his students were able to show statistically significant growth over their predicted scores on the Keystone Algebra I Exam. This growth led to Lampeter-Strasburg High School achieving the third highest ranking in the state with their average growth index in 2016 (see Appendix D).

Appendix A: Predicted & Actual Keystone Algebra I Scores, L-S Algebra I, 2013–2016

(Values in bold text indicate actual scores that were greater than predicted scores. Green cells indicate proficient scores, while blue cells indicate scores that were not proficient but still exceeded the predicted score.)

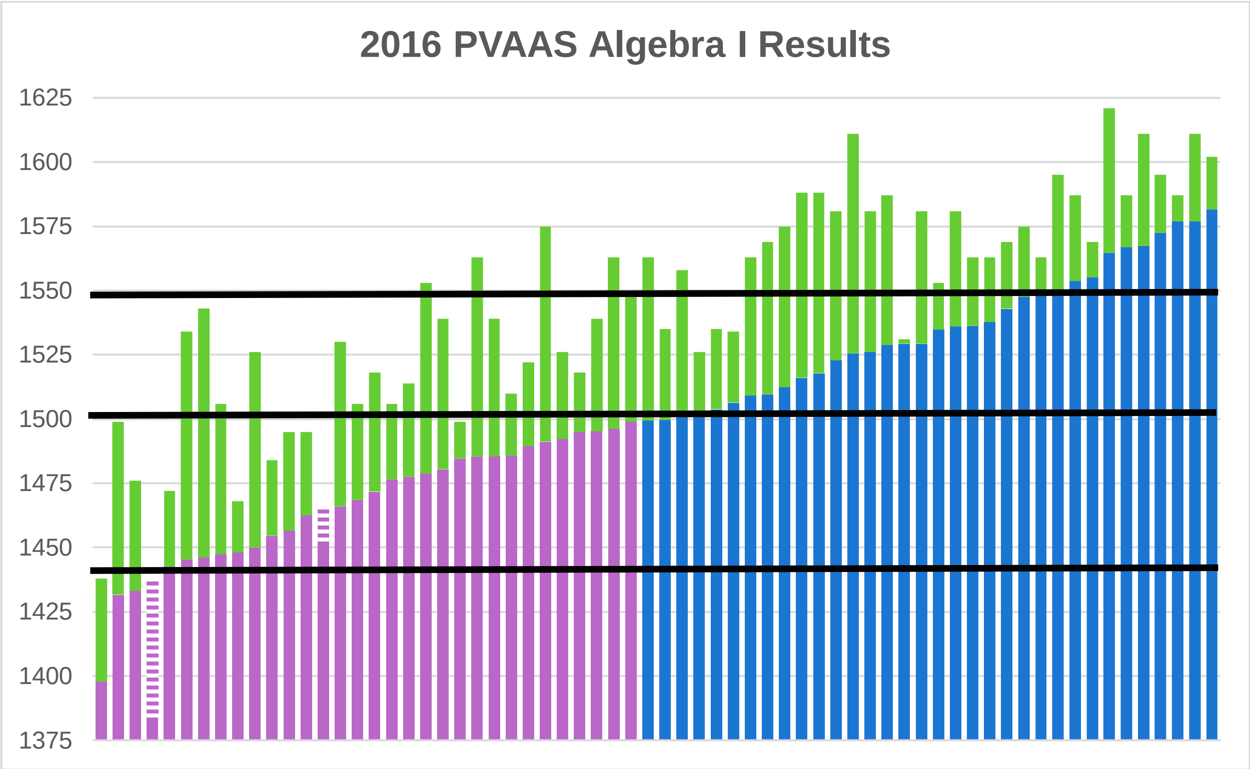
Predicted	Actual
1581.7	**1602**
1577	**1611**
1576.9	**1587**
1573.2	**1649**
1572.4	**1595**
1567.5	**1611**
1566.9	**1587**
1565.9	**1588**
1564.8	**1621**
1556.3	**1595**
1555.4	**1622**
1555.3	**1569**
1553.8	**1587**
1550.6	**1595**
1549.4	**1591**
1548.8	**1563**
1548.7	**1563**
1547.6	**1575**
1547	**1569**
1545.7	**1595**
1543.4	**1581**
1543.2	**1557**
1542.9	**1569**
1539	**1600**
1538	**1576**
1537.7	**1563**
1537.2	**1612**
1537	**1582**
1537	**1574**
1536.7	**1575**
1536.5	**1587**
1536.2	**1563**
1536	**1581**
1534.8	**1553**
1533.8	1526
1533.8	1512
1533.3	**1581**
1533.3	1524
1533.2	**1595**
1533	**1588**
1532.8	**1604**
1532.4	**1588**
1532.4	**1583**
1531.7	**1625**
1531.1	**1570**
1530.5	**1538**
1529.6	**1595**
1529.3	**1581**
1529.3	**1531**
1529.1	**1560**
1528.8	**1587**
1528.4	**1569**
1528.3	**1565**
1527.9	1520
1527.5	**1570**
1527.1	**1563**
1526.7	**1591**
1526.7	**1547**
1526.1	**1581**
1525.9	**1595**
1525.7	**1547**
1525.6	**1611**
1525.1	1523
1525	**1565**
1524.9	**1588**
1524.2	**1531**
1523.6	**1521**
1523.5	1481
1523	**1549**
1522.9	**1581**
1522.2	1517
1520.6	**1550**
1520	**1543**
1517.8	**1588**
1517.7	**1587**
1517.5	**1560**
1517.4	**1541**
1517.3	**1536**
1516.9	**1549**
1516	**1588**
1515.2	**1634**
1515.1	**1576**
1514.9	**1521**
1514.8	**1570**
1514.8	**1569**
1513.9	**1551**
1513.8	**1544**
1512.4	**1575**
1512.3	**1528**
1510	**1565**
1509.7	**1536**
1509.6	**1569**
1509.2	**1563**
1507.8	1495
1507.6	1488
1507.1	**1555**
1507.1	**1520**
1506.3	**1534**
1506.1	**1547**
1505.8	**1531**
1504.4	**1560**
1504.2	**1538**
1504.1	**1555**
1504	**1569**
1503.9	**1532**
1503.8	**1565**
1503.8	**1535**
1503.7	**1540**
1503.2	**1526**
1502.9	**1563**
1502.5	**1604**
1502.1	**1543**
1501.8	**1537**
1501.4	**1558**
1501.4	**1526**
1501.2	**1502**
1501.1	**1595**
1501	**1531**
1500.8	**1550**
1499.6	**1535**
1499.5	**1563**
1499	**1548**
1498.4	**1558**
1498.4	**1550**
1498	**1517**
1496.8	1489
1496.7	**1543**
1496.3	**1563**
1496.1	**1502**
1496	**1553**
1495.8	**1521**
1495.7	**1534**
1495.3	**1539**

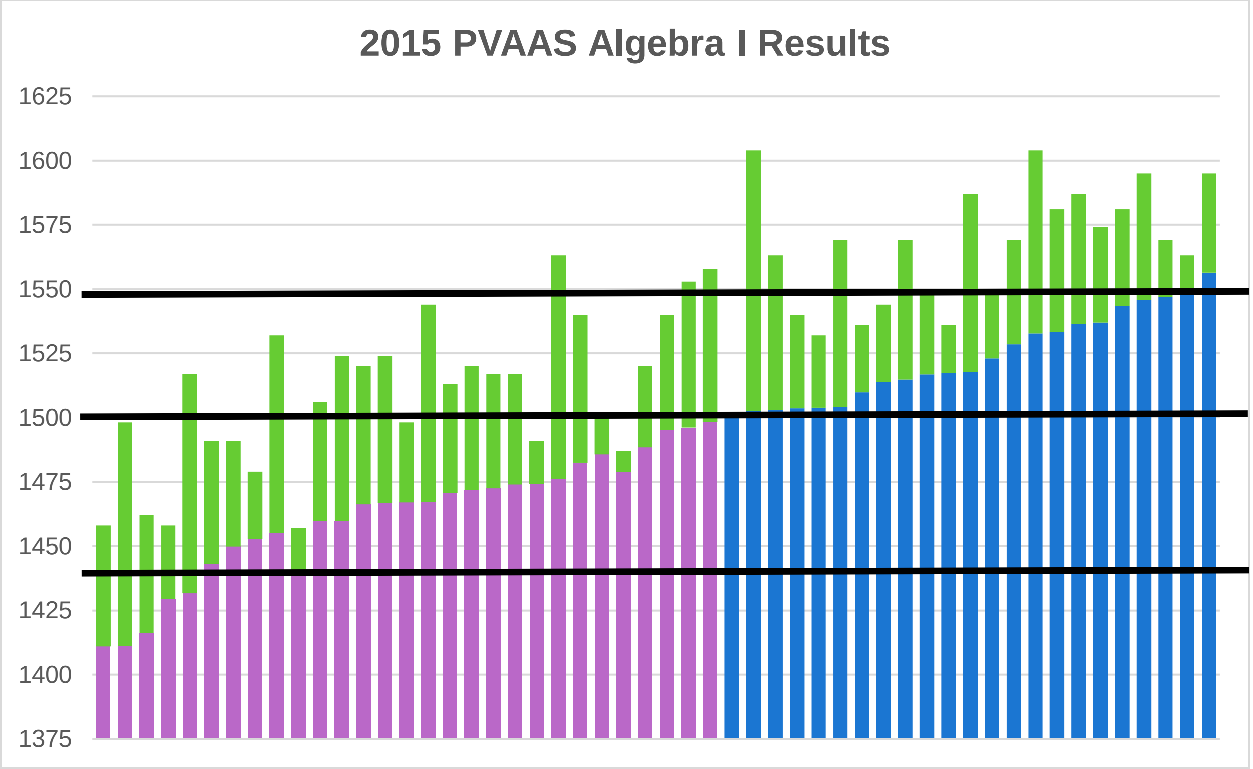
1495.2	**1540**
1495.2	**1523**
1495	**1546**
1495	**1518**
1494.3	**1576**
1494.3	**1528**
1493.8	**1524**
1492.4	**1520**
1492.3	**1526**
1492.3	**1515**
1491.8	**1570**
1491.7	**1530**
1491.4	**1533**
1491.2	**1498**
1491.1	**1575**
1490.7	**1539**
1490.6	**1507**
1490.5	**1503**
1490.4	**1500**
1490.2	**1521**
1489.5	**1522**
1489.3	**1533**
1489	**1491**
1488.5	**1528**
1488.4	**1520**
1488.1	**1547**
1487.5	**1537**
1487	1479
1486.7	**1496**
1485.8	**1510**
1485.6	**1539**
1485.6	**1502**
1485.4	**1563**
1484.8	**1528**
1484.7	**1547**
1484.7	**1499**
1484.5	**1521**
1484.4	**1541**
1483.6	**1555**
1483.6	**1528**
1482.3	**1540**
1481.7	**1524**
1481	**1496**
1480.8	**1489**

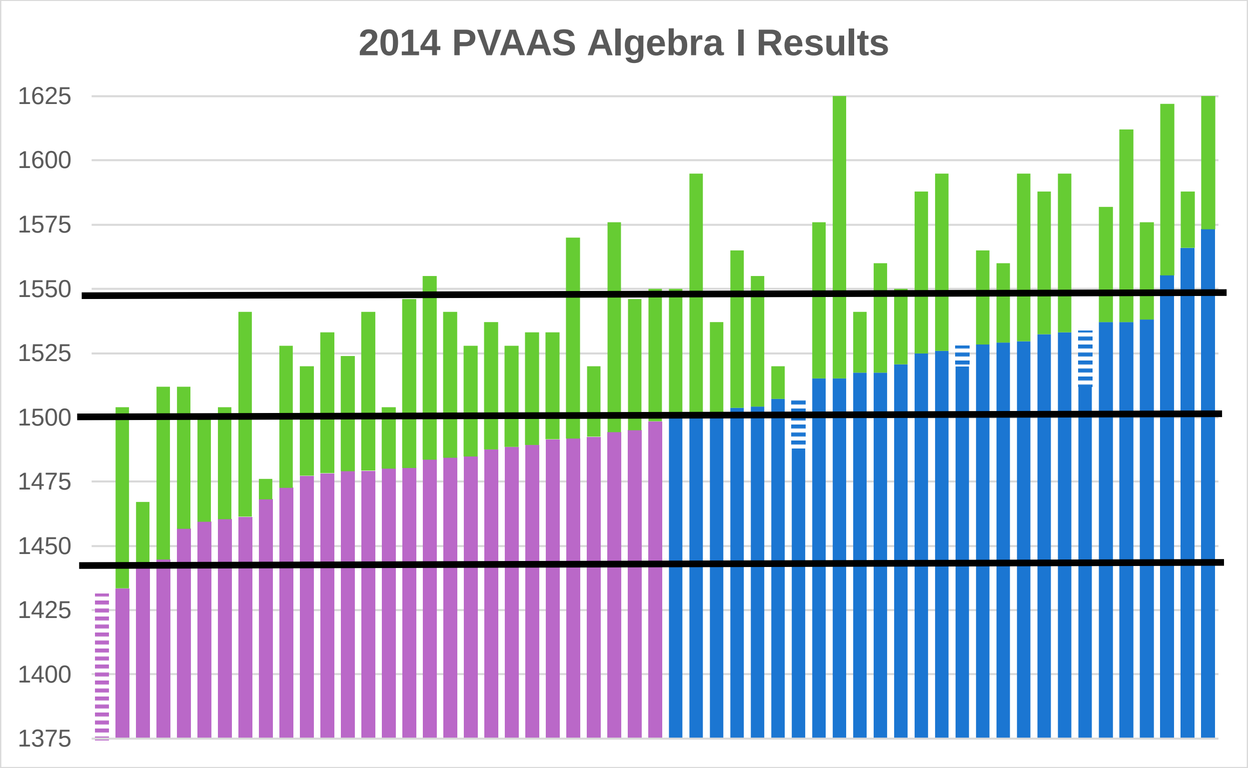
1480.4	**1546**
1480.4	**1539**
1480.1	**1504**
1479.8	**1503**
1479.7	**1514**
1479.2	**1541**
1479.1	**1524**
1478.8	**1553**
1478.2	**1533**
1478.2	**1521**
1477.9	**1507**
1477.4	**1521**
1477.4	**1514**
1477.2	**1520**
1476.4	**1506**
1476.2	**1563**
1475.7	**1514**
1475	1474
1474.2	**1491**
1474	**1517**
1473.9	**1500**
1472.6	**1528**
1472.4	**1517**
1472.4	**1496**
1472	**1514**
1471.7	**1518**
1471.6	**1520**
1470.8	**1513**
1469.6	**1496**
1468.5	**1506**
1468.2	**1476**
1467.3	**1544**
1467.1	**1498**
1466.8	**1524**
1466.3	**1520**
1466.1	**1503**
1466	**1530**
1465.3	**1485**
1464.8	1452
1464.4	**1496**
1463.4	**1510**
1462.6	**1495**
1462.3	**1474**
1461.3	**1541**

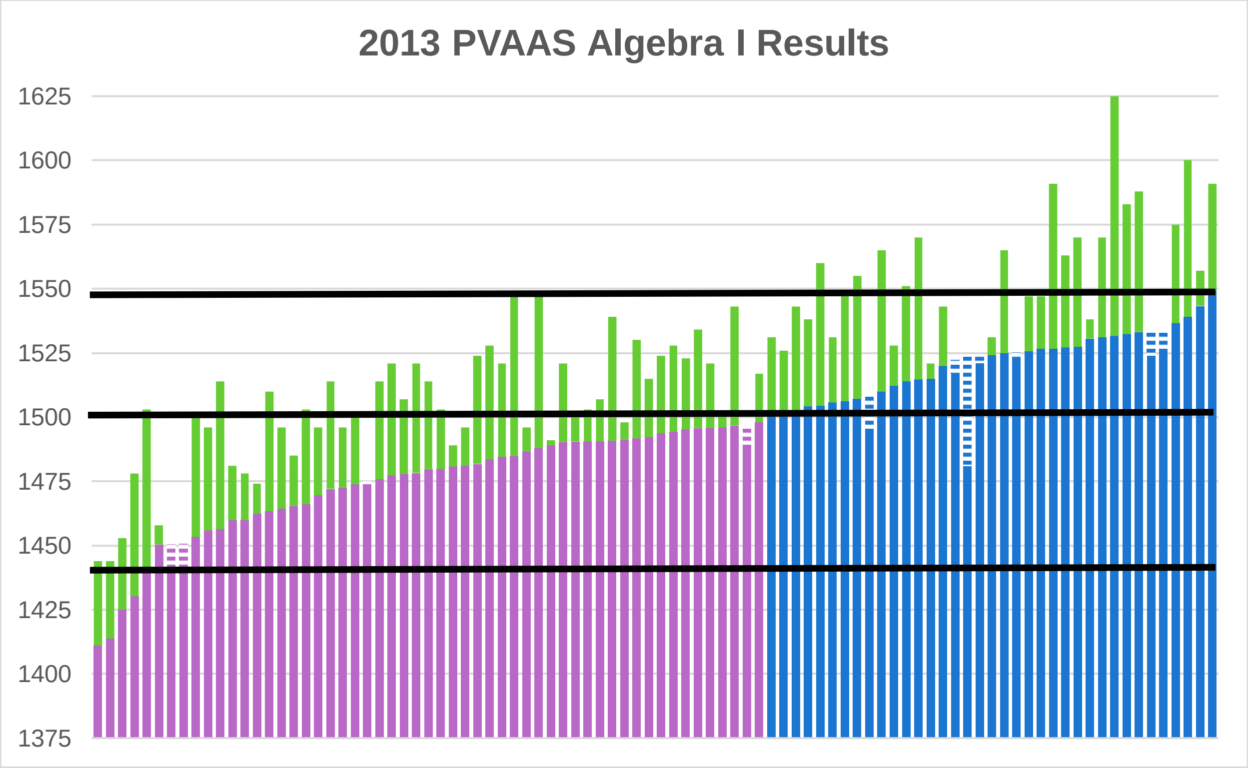
1460.4	**1504**
1460	**1478**
1459.8	**1524**
1459.8	**1481**
1459.7	**1506**
1459.4	**1500**
1457.1	1439
1456.7	**1512**
1456.7	**1495**
1456.5	**1514**
1455.9	**1496**
1454.9	**1532**
1454.5	**1484**
1453.5	**1500**
1452.7	**1479**
1450.6	1439
1450.4	**1458**
1450.4	1439
1450.1	**1526**
1449.8	**1491**
1448.2	**1468**
1447.5	**1506**
1446.2	**1543**
1445.4	**1534**
1444.6	**1512**
1443.7	**1467**
1443.1	**1491**
1442.7	**1472**
1441.7	**1503**
1436.7	1384
1433.4	**1504**
1433.3	**1476**
1431.6	**1499**
1431.5	**1517**
1431.4	1371
1430.2	**1478**
1429.3	**1458**
1425	**1453**
1416.2	**1462**
1413.9	**1444**
1411.2	**1498**
1411.1	**1444**
1410.9	**1458**
1397.8	**1438**

Appendix B: PVAAS Growth Results, L-S Algebra I, 2013–2016






2014 PVAAS Algebra I Results
1625
1600
1575
1550
1525
1500
1475
1450
1425
1400
1375


2013 PVAAS Algebra I Results
1625
1600
1575
1550
1525
1500
1475
1450
1425
1400
1375

Appendix C: Statistical Tests

Actual Scores of Get More Math Students vs. Predicted Scores

Summary statistics:

Column	n	Mean	Variance	Std. dev.	Std. err.
predicted	265	1495.90	1239.610	35.20810	2.16281
actual	265	1534.23	1813.386	42.58387	2.61590

Two sample T hypothesis test:

μ_1: Mean of actual
μ_2: Mean of predicted
$\mu_1 - \mu_2$: Difference between two means
H_0: $\mu_1 - \mu_2 = 0$
H_A: $\mu_1 - \mu_2 > 0$
(without pooled variances)

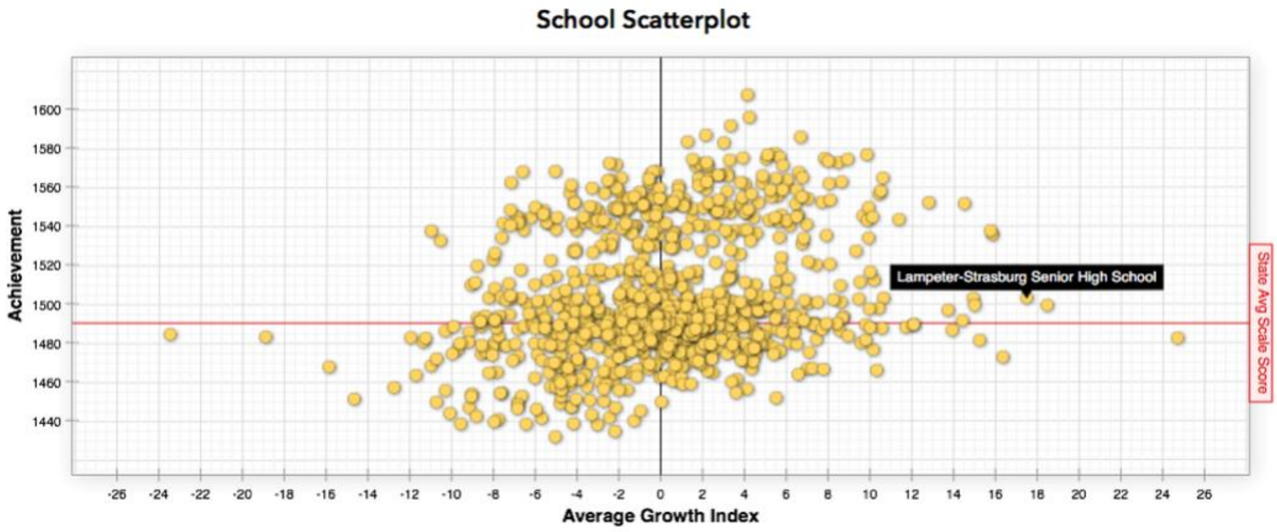
Hypothesis test results:

Difference	Sample Diff.	Std. Err.	DF	T-Stat	P-value
$\mu_1 - \mu_2$	38.328679	3.3942221	509.98681	11.292331	<0.0001

Effect Size for Actual Scores of Get More Math Students vs. Predicted Scores

$$d = \frac{38.328679}{\sqrt{\frac{42.58387^2 + 35.2081^2}{2}}} = 0.981 > 0.8$$

Appendix D: PVAAS Achievement vs. Average Growth Scatterplot, 2016



2016 Achievement vs. Average Growth Index, Pennsylvania Schools

References

Brown, P.C., Roediger, H.L., III, & McDaniel, M.A. (2014). *Make it stick: The science of successful learning.* The Belknap Press of Harvard University Press.

Kim, J.W., Ritter, F.E., & Koubek, R.J. (2013). An integrated theory for improved skill acquisition and retention in the three stages of learning. *Theoretical Issues in Ergonomics Science, 14*(1), 22-37. http://dx.doi.org/10.1080/1464536X.2011.573008

Little, C.A., Hauser, S., & Corbishley, J. (2009). Constructing complexity for differentiated learning. *Mathematics Teaching in the Middle School, 15*(1), 34-42. https://www.jstor.org/stable/41182949

Murray, T. & Arroyo, I. (2002, June 2). *Toward measuring and maintaining the zone of proximal development in adaptive instructional systems*. International Conference on Intelligent Tutoring Systems, 749-758. San Sebastian, Spain. 10.1007/3-540-47987-2_75

National Center for Education Statistics. (n.d.). *School directory information – Lampeter Strasburg SHS*. Retrieved March 22, 2022, from https://nces.ed.gov/ccd/

Pennsylvania Department of Education. (2021a). *What should you know about PVAAS?* https://www.education.pa.gov/Documents/K-12/Assessment%20and%20Accountability/PVAAS/WhatShouldYouKnowAboutPVAAS.pdf

Pennsylvania Department of Education. (2021b). *PVAAS methodologies: measuring growth & projecting achievement.* https://www.education.pa.gov/Documents/K-12/Assessment%20and%20Accountability/PVAAS/Methodology/PVAASMethodologies.pdf

Roediger, H. L., & Karpicke, J. D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science*, 17(3), 249–255. https://doi.org/10.1111/j.1467-9280.2006.01693.x

SAS Institute, Inc. (2022). *PVAAS scatterplots.* https://pvaas.sas.com/scatterplot.html?as=d&aj=d&w4=116&ab=dD&x9=1&xp=2999&yb=1&wD=-1&x7=2

Schleicher, A. (2019). *PISA 2018: Insights and interpretations*. Organisation for Economic Cooperation and Development.