CARNEGIE LEARNING

# MATHia® Data Reviews

Put Them to Work for You

## Background

MATHia® is Carnegie Learning's intelligent tutoring system for grades 6-12 mathematics. It offers guided instruction, tailored mastery exercises, and easy-to-understand reports for educators. MATHia also collects extensive metrics on student effort and performance. As an adaptive instructional system, MATHia continually assesses student knowledge of fine-grained skills. These assessments can not only guide learning but can give us a very complete picture of student knowledge, which can be used to predict student performance on state end-of-year assessments. We call this model APLSE (Adaptive Personalized Learning Score).

We have found the correlations between APLSE scores and state- and district-summative assessment scores to be valid and strong across a wide variety of student demographic groups, school districts, and outcome measures. Additionally, the APLSE scores are strong predictors of end-of-year test scores. The APLSE model is backed by extensive, peer-reviewed research (Fancsali et al., 2018; Joshi et al., 2014; Ritter et al., 2013; Zheng et al., 2019).

State End-of-Grade and End-of-Course assessments used in Carnegie Learning's analyses have included:

- Florida Standards Assessment (FSA), Grades 6-8
- Florida Comprehensive Assessment Test (FCAT), Grades 6-8
- Ohio's State Test (OST) Grades 6-8, Algebra I and Geometry End-of-Course Tests
- Virginia Standards of Learning (SOL), Grades 6-8
- West Virginia's Educational Standards Test 2 (WESTEST2), mostly Grade 9
- California's Assessment of Student Performance and Progress (CAASPP), Grades 6-8, Grade 11
- Illinois Assessment of Readiness (IAR), Grades 6-7
- South Carolina's SC Ready, Grades 6-8, Algebra I End-of-Course test
- Texas, STAAR Grades 6-8, and Algebra I End-of-Course Tests

National assessments used have included:

- Smarter Balanced Assessment End-of-Year Scores, Grades 6-8, Grade 10
- NWEA's MAP assessment for mathematics, Grades 6-8

Appendix 1 gives detailed statistical information about each of these studies.

## MATHia Implementation

Successful student use of MATHia occurs at three levels, each of which requires all previous levels.

1. **Time:** Students must be provided with an adequate amount of time in MATHia to master the content covered on the test. A typical student will need 40-50 hours of MATHia usage to successfully complete a full year's curriculum.

2. **Productivity:** Students need to make good use of the time they spend using the software. One measure of productivity is the number of workspaces students complete. Successful students typically complete 1-2 workspaces/hour.

3. **Mastery:** Students need to master the mathematical skills they encounter in MATHia. Combined with vital instructional support from teachers, the tailored practice, feedback, and just-in-time assistance MATHia provides 'push students along' this mastery path. Successful students master over 80% of the workspaces that they encounter.

# APLSE Scores

MATHia users might be tempted to use each of the implementation factors described above to predict student performance on interim and end-of-grade assessments—an unnecessary effort. The APLSE scores are a composite of Time, Productivity, and Performance variables. The APLSE score predicts interim and end-of-grade test scores better than any of its component features.

# Data Reviews

Our partners are interested in learning more about how their districts and schools are using MATHia and about how well APLSE scores predict interim and end-of-grade assessments. To this aim, Carnegie Learning offers customized data reviews to its MATHia partners. A data review is a set of analyses typically covering:

- MATHia implementation by school.
- Predicted end-of-year summative test scores given APLSE scores and correlations between APLSE scores and the summative test scores. In data reviews completed to date, the median correlation by grade or course level ranged from .55–.63.
- Predicted percent of MATHia-proficient students also reaching proficiency on the end-of-grade test score. In data reviews completed to date, the median of this statistic by grade or course level ranged from 79% to 92%.
- Predicted gains on end-of-year state test scores for every ten additional APLSE score points earned. The following table shows the median predicted EOY gains on state test scores per every 10 APLSE score points earned by state tests.

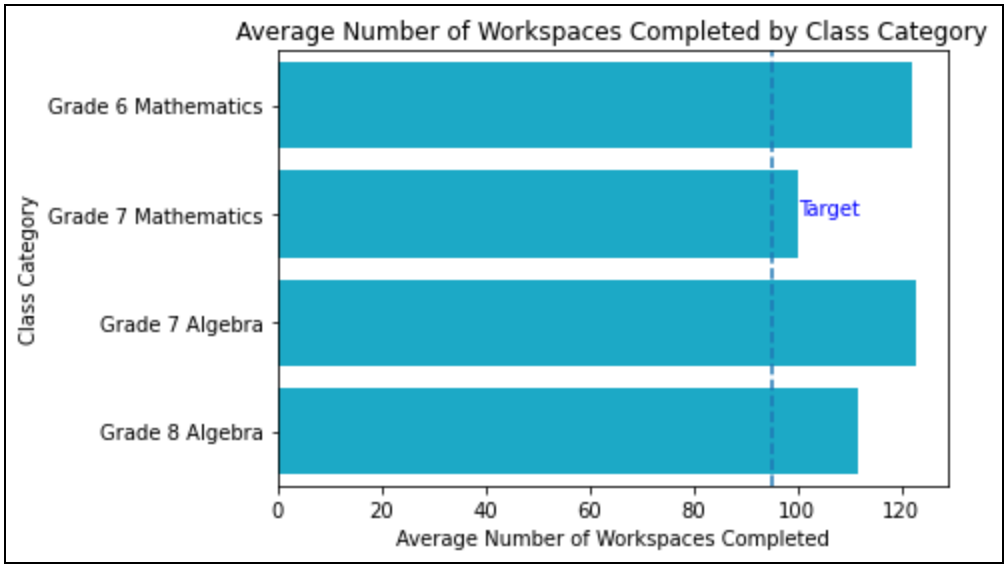
**Median Predicted EOY Gains Per Every 1-Point APLSE Score Gain**

| State | Test | Median EOY Gains per 10 APLSE points |
|---|---|---|

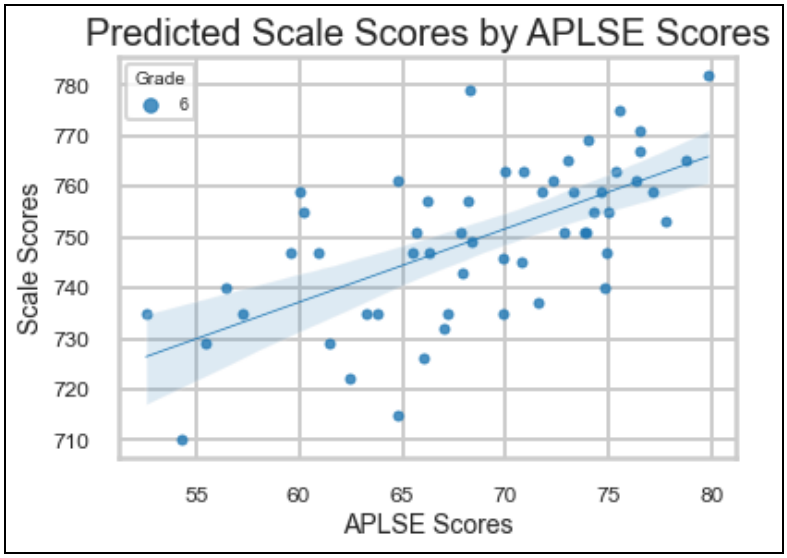
| | | |
|---|---|---|
| **IL** | IAR | 10.9 |
| **OH** | OST Grades 6,7,8 | 8.3 |
| | OST A1 EOC | 10.2 |
| | OST G EOC | 8.8 |
| **SC** | SC Ready | 28.3 |
| | SC A1 EOC | 2.4 |
| **TX** | TX STAAR Grades 6, 7, 8 (Previous Edition) | 48.5 |
| | TX STAAR Grades 6, 7, 8 (New Edition) | 28.0 |
| | TX A1 EOC (Previous Edition) | 23.8 |
| | TX A1 EOC(New Edition) | 77.5 |
| **WA** | SBAC | 15.6 |

# Examples from Recent Data Reviews

The figure below shows a typical MATHia usage plot using real but anonymized data. The horizontal bars show the average number of workspaces completed for each class group, and the dashed vertical line marks a target number of workspaces students would ideally complete over the school year. For example, the plot below shows that Grade 6 and Grade 7 mathematics students have the highest average number of workspaces completed.




The next figure shows a recently completed data review's depiction of the relationship between the MATHia APLSE score and the end-of-year test by grade. The colors of dots and lines represent student grade. Each dot represents a student. Specifically, each dot sits at *x* and *y* coordinates for MATHia performance and end-of-year mathematics scores for that student. The slanted lines show the predicted end-of-year test score (*y*-axis) for each possible value of the MATHia APLSE score. The shaded region around each slanted line represents a margin of error. In this particular example, the correlation between APLSE and the state test's scale scores was .61. Also, every 10-point increase in APLSE scores was associated with a 14-point increase in the state test's scale scores.




The following figure shows the crosstabulation tables CL typically uses to show the percentage of MATHia-proficient students who are also proficient on the end-of-year tests. The key numbers are in the final column. To calculate the percent of MATHia-proficient students who are also proficient on the

end-of-year test, the sum of the last two cells in the MATHia-proficient column is divided by the column sum and multiplied by 100, specifically, (44 + 156)/(1 + 23 + 44 + 156)*100 to yield 89%.

Grade 6. APLSE Proficiency Level by State Test Performance Level

| State Test Performance Level | Off Track | Approaching | On Track |
|---|---|---|---|
| Does Not Meet | 30 (15%) | 4 (3%) | 1 (0%) |
| Approaches | 80 (39%) | 32 (27%) | 23 (10%) |
| Meets | 60 (29%) | 33 (28%) | 44 (20%) |
| Masters | 34 (17%) | 48 (41%) | 156 (70%) |

APLSE-proficient students at or above proficiency on state test.

# Uses of Information from Data Reviews

**Potential Uses for Data Review Information**

| User | Use |
|---|---|
| **Teachers** | • Identify students at risk for not reaching proficiency on the end-of-year test.<br>• Encourage students by showing them the relationship between the number of assignments completed and end-of-year success. |
| **Principals** | • Identify high- and low-usage classes.<br>• Identify which students are predicted to be proficient on their end-of-grade test given their MATHia performance level. |
| **District Administrators** | • Identify high- and low-usage schools.<br>• Identify which students are predicted to be proficient on their end-of-grade test given their MATHia performance level. |
| **Policy Makers** | • Provide quantitative evidence for using high-quality, embedded assessments such |

| | |
|---|---|
| | as MATHia in place of recurring, standardized formative assessments. |

*Cautionary Notes:* Statistical relationships do not provide hard-and-fast truths. Many artifacts can adversely affect the size of correlations and regression slopes and also classification accuracy statistics. For instance:

- Correlations indicate the strength of a statistical association between two variables. They do not indicate whether one variable caused the other.
- Correlations between APLSE scores and outcome variables may increase or decrease depending on how well the content of the end-of-year test and the students' MATHia curriculum align.
- Correlations may decrease when one or two of the variables do not have the full range of values they would typically have. This often happens in grade 8 end-of-year samples when higher-ability students are siphoned off the sample because they do not take the end-of-grade exam but rather the Algebra I end-of-course exam.
- Correlations may increase when the state test has especially good reliability. The reliability, or the consistency of scoring, of a test, is the upper bound of any correlation it might have with another instrument.
- Correlations fluctuate across samples even when they are drawn from the same population.
- Classification accuracy statistics can be greatly affected by what is called the base rate. In these studies, the base rate is the proportion of students reaching proficiency on the end-of-grade test. The classification accuracy metric reported is the proportion of MATHia-proficient students who are also proficient on the end-of-year tests. This rate decreases as the base rate decreases from 50 percent. Conversely, this rate increases as the base rate increases from 50 percent. The figure gives an example of this phenomenon. In each case, the total number of fictitious students was 100, and the overall accuracy of classification was 80 percent. The base rates shown are 50 percent, 10 percent, and 90 percent.
- Students can learn mathematics elsewhere than in MATHia, e.g., books and tutors. It's entirely possible for students to be proficient on the state test and not APLSE-proficient.

# Summary

1. MATHia performance scores have a strong relationship with end-of-grade performance on many end-of-year mathematics state tests.

2. MATHia performance levels are highly predictive of students' proficiency on end-of-year state mathematics tests.

3. MATHia data reviews provide summaries of student usage by school, as well as information about the relationships between MATHia and end-of-year performance on state assessments.

# Contact Information

Carnegie Learning staff are eager to do a data review for your district. To learn how to get started, please contact your Manager of School Partnerships or research@carnegielearning.com.

# References


Fancsali, S. E., Zheng, G., Tan, Y., Ritter, S., Berman, S. R., & Galyardt, A. (2018). Using Embedded Formative Assessment to Predict State Summative Test Scores. *Proceedings of the 8th International Conference on Learning Analytics and Knowledge*, 161–170. https://doi.org/10.1145/3170358.3170392

Joshi, A., Fancsali, S. E., Ritter, S., Nixon, T., & Berman, S. R. (2014). Generalizing and Extending a Predictive Model for Standardized Test Scores Based on Cognitive Tutor Interactions. *Proceedings of the 7th International Conference on Educational Data Mining*, 369–370.

Ritter, S., Joshi, A., Fancsali, S., & Nixon, T. (2013). Predicting Standardized Test Scores from Cognitive Tutor Interactions. *Proceedings of the 6th International Conference on Educational Data Mining*.

Zheng, G., Fancsali, S. E., Ritter, S., & Berman, S. (2019). Using Instruction-Embedded Formative Assessment to Predict State Summative Test Scores and Achievement Levels in Mathematics. *Journal of Learning Analytics, 6*(2) https://doi.org/10.18608/jla.2019.62.11

# Appendix 1. Supplementary Statistics

**Table A1. Summary Statistics Including MATHia-Target Test Correlations from Data Reviews and Research Studies, 2012-2023**

| State | District | Target Test | School Year | Grade | Term | Final *N* | *r* | Slope 10x |
|---|---|---|---|---|---|---|---|---|
| **FL** | District 1 | FCAT | 2013-2014 | G6, G7, G8 | — | 7,941 | 0.74* | NA |
| **FL** | District 1 | FSA | 2014-2015 | G6, G7, G8 | — | 7,368 | 0.73* | NA |
| **FL** | District 1 | FSA | 2015-2016 | G6, G7, G8 | — | 8,065 | 0.77* | NA |
| **IL** | District 1 | IAR | 2021-22 | 6 | — | 69 | 0.65 | 7.8 |
| **IL** | District 1 | IAR | 2021-22 | 7 | — | 73 | 0.80 | 6.2 |
| **IL** | District 1 | IAR | 2021-22 | A1-7 | — | 25 | 0.80 | NA |
| **IL** | District 1 | IAR | 2022-23 | 6 | — | 55 | 0.63 | 14.0 |
| **IL** | District 1 | IAR | 2022-23 | 7 | — | 71 | 0.60 | 17.0 |
| **OH** | District 1 | OST | 2021-22 | 6 | — | 496 | 0.79 | 8.0 |
| **OH** | District 1 | OST | 2021-22 | 7 | — | 532 | 0.64 | 8.5 |
| **OH** | District 1 | OST | 2021-22 | 8 | — | 418 | 0.50 | 4.1 |
| **OH** | District 1 | OH A1-EOC | 2021-22 | A1 | — | 988 | 0.79 | 10.2 |
| **OH** | District 1 | OH G-EOC | 2021-22 | G | — | 785 | 0.71 | 15.2 |
| **OH** | District 1 | OST | 2022-23 | 6 | — | 546 | 0.79 | 10.2 |
| **OH** | District 1 | OST | 2022-23 | 7 | — | 467 | 0.70 | 9.4 |
| **OH** | District 1 | OST | 2022-23 | 8 | — | 381 | 0.56 | 4.1 |
| **OH** | District 1 | OH A1-EOC | 2022-23 | A1-8 | — | 120 | 0.60 | 13.1 |
| **OH** | District 1 | OH A1-EOC | 2022-23 | A1-9 | — | 397 | 0.64 | 9.1 |
| **OH** | District 1 | OH G-EOC | 2022-23 | G-9 | — | 111 | 0.50 | 8.8 |
| **OH** | District 1 | OH G-EOC | 2022-23 | G-10 | — | 303 | 0.48 | 7.8 |
| **OH** | District 2 | MAP | 2021-22 | 6 | F | 1,324 | 0.29 | 1.3 |
| **OH** | District 2 | MAP | 2021-22 | 6 | W | 1,351 | 0.63 | 2.3 |
| **OH** | District 2 | MAP | 2021-22 | 6 | S | 802 | 0.57 | 2.2 |
| **OH** | District 2 | MAP | 2021-22 | 7 | F | 1,131 | 0.29 | 1.7 |
| **OH** | District 2 | MAP | 2021-22 | 7 | W | 1,144 | 0.58 | 2.1 |

| State | District | Target Test | School Year | Grade | Term | Final *N* | *r* | Slope 10x |
|---|---|---|---|---|---|---|---|---|
| **OH** | District 2 | MAP | 2021-22 | 7 | S | 747 | 0.49 | 1.8 |
| **OH** | District 2 | MAP | 2021-22 | 8 | F | 794 | 0.27 | 2.5 |
| **OH** | District 2 | MAP | 2021-22 | 8 | W | 809 | 0.41 | 1.9 |
| **OH** | District 2 | MAP | 2021-22 | 8 | S | 560 | 0.39 | 1.9 |
| **SC** | District 1 | SC Ready | 2021-22 | 6 | — | 5,134 | 0.75 | 38.5 |
| **SC** | District 1 | SC Ready | 2021-22 | 7 | — | 5,133 | 0.73 | 28.3 |
| **SC** | District 1 | SC Ready | 2021-22 | 8 | — | 4,945 | 0.65 | 23.9 |
| **SC** | District 1 | SC A1-EOC | 2021-22 | A1-8 | — | 1,102 | 0.53 | 2.1 |
| **SC** | District 1 | SC A1-EOC | 2021-22 | A1-9 | — | 1,064 | 0.35 | 2.7 |
| **TX** | District 1 | STAAR | 2021-22 | 6 | — | 3,177 | 0.48 | 48.0 |
| **TX** | District 1 | STAAR | 2021-22 | 7 | — | 3,440 | 0.58 | 44.6 |
| **TX** | District 1 | STAAR | 2021-22 | 8 | — | 2,809 | 0.56 | 67.9 |
| **TX** | District 1 | TX A1-EOC | 2021-22 | A1-8 | — | 430 | 0.65 | 17.7 |
| **TX** | District 1 | TX A1-EOC | 2021-22 | A1-9 | — | 2,074 | 0.53 | 23.8 |
| **TX** | District 2 | STAAR | 2021-22 | 6 | — | 768 | 0.46 | 43.7 |
| **TX** | District 2 | STAAR | 2021-22 | 7 | — | 652 | 0.43 | 88.0 |
| **TX** | District 2 | STAAR | 2021-22 | 8 | — | 384 | 0.55 | 84.1 |
| **TX** | District 3 | MAP | 2021-22 | 6 | F | 1,154 | 0.59 | NA |
| **TX** | District 3 | MAP | 2021-22 | 6 | W | 1,380 | 0.56 | NA |
| **TX** | District 3 | STAAR | 2021-22 | 6 | — | 1,452 | 0.62 | 51.2 |
| **TX** | District 3 | MAP | 2021-22 | 7 | F | 1,056 | 0.43 | NA |
| **TX** | District 3 | MAP | 2021-22 | 7 | W | 1,268 | 0.51 | NA |
| **TX** | District 3 | STAAR | 2021-22 | 7 | — | 1,212 | 0.67 | 48.5 |
| **TX** | District 3 | MAP | 2021-22 | 8 | F | 1,097 | 0.42 | NA |
| **TX** | District 3 | MAP | 2021-22 | 8 | W | 1,277 | 0.60 | NA |
| **TX** | District 3 | STAAR | 2021-22 | 8 | — | 1,151 | 0.54 | 26.0 |
| **TX** | District 3 | A1 EOC | 2021-22 | — | — | 1,113 | 0.63 | 168.8 |
| **TX** | District 3 | MAP | 2022-23 | 6 | F | 1,773 | 0.56 | NA |
| **TX** | District 3 | MAP | 2022-23 | 6 | W | 1,889 | 0.58 | NA |
| **TX** | District 3 | STAAR | 2022-23 | 6 | — | 1,756 | 0.60 | 28.0 |
| **TX** | District 3 | MAP | 2022-23 | 7 | F | 1,686 | 0.45 | NA |
| **TX** | District 3 | MAP | 2022-23 | 7 | F | 1,694 | 0.59 | NA |

| State | District | Target Test | School Year | Grade | Term | Final *N* | *r* | Slope 10x |
|---|---|---|---|---|---|---|---|---|
| **TX** | District 3 | STAAR | 2022-23 | 7 | W | 1,647 | 0.60 | 28.0 |
| **TX** | District 3 | MAP | 2022-23 | 8 | F | 1,502 | 0.44 | NA |
| **TX** | District 3 | MAP | 2022-23 | 8 | W | 1,542 | 0.55 | NA |
| **TX** | District 3 | STAAR | 2022-23 | 8 | — | 1,115 | 0.52 | 19.0 |
| **TX** | District 3 | A1-EOC | 2022-23 | HS | — | 974 | 0.38 | 52.0 |
| **TX** | District 3 | A1-EOC | 2022-23 | MS | — | 545 | 0.61 | 103.0 |
| **VA** | District 1 | SOL | 2011-2012 | 6 | — | 1,060 | 0.68* | NA |
| **VA** | District 1 | SOL | 2011-2012 | 7 | — | 1,354 | 0.66* | NA |
| **VA** | District 1 | SOL | 2011-2012 | 8 | — | 810 | 0.42* | NA |
| **VA** | District 1 | MAP | 2011-2012 | 6 | — | 1,060 | 0.69* | NA |
| **VA** | District 1 | MAP | 2011-2012 | 7 | — | 1,354 | 0.70* | NA |
| **VA** | District 1 | MAP | 2011-2012 | 8 | — | 810 | 0.51* | NA |
| **WA** | District 1 | SBAC | 2021-22 | 6 | — | 247 | 0.47 | 14.5 |
| **WA** | District 1 | SBAC | 2021-22 | 7 | — | 1,096 | 0.40 | 14.2 |
| **WA** | District 1 | SBAC | 2021-22 | 8 | — | 1,072 | 0.40 | 16.6 |
| **WA** | District 1 | SBAC | 2021-22 | 10 | — | 932 | 0.56 | 28.3 |
| **WV** | District 1 | WESTEST2 | 2012-13 | Mostly G9 | — | 636 | 0.57* | NA |

*Multiple correlation from predictive model