

Original Research Article

Opportunity to learn and mathematics achievement: The roles of content coverage and instructional time in TIMSS 2023

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Abstract: Opportunity to learn (OTL) is often introduced through curriculum policy, but students meet it in a more practical form: The mathematics topics their teacher covers and the time set aside for those topics. This paper examines how these two classroom indicators are related to Grade 8 mathematics achievement in TIMSS 2023. Public-use student, mathematics-teacher, and student-teacher linkage files were brought together for the 47 education systems that supplied all three files. The final analytic sample contained 112,827 complete student-mathematics-teacher links, representing 111,954 individual students in 46 systems and 8,259 schools. Mathematics achievement was represented by five TIMSS plausible values. Content coverage was calculated as the mean percentage of students taught number, algebra, geometry/measurement, and data/probability topics. Instructional time was the teacher-reported number of mathematics hours per week. The weighted least-squares models adjusted for home educational resources, student sex, and education-system fixed effects. Each system received the same total analytic weight. Estimates were first calculated for each of the five plausible values and were then combined with Rubin's rules; standard errors were clustered by school. Average coverage was 79.67%, while mean weekly mathematics time was 3.87 hours. A one-standard-deviation increase in composite content coverage (16.27 percentage points) was associated with a 4.06-point higher mathematics score ($SE = 1.06$, $p < .001$). Instructional time did not show a clear linear association at the mean, although the small negative quadratic term was statistically distinguishable from zero. In the domain model, the clearest positive association was for number coverage. Algebra was weaker, and geometry/measurement and data/probability were not statistically clear. Overall, the results suggest that a reasonably broad coverage of content may tell us more about OTL than simply adding lesson time. The data are cross-sectional and coverage is partly based on teacher reports, so the findings are adjusted associations rather than causal effects.

Keywords: opportunity to learn; mathematics achievement; TIMSS 2023; curriculum coverage; instructional time; secondary data analysis

1. Literature review

1.1. Opportunity to learn as enacted curriculum

International assessment data offer a useful, although limited, way to examine this issue TIMSS combines mathematics success with data from the whole system. The questionnaires are from students, schools, teachers, and curriculum. This makes it... possible to connect performance with some indicators of the conditions in which Learning occurred. Drent et al. (2013) assessed this contribution of TIMSS. and stressed the benefit of considering school and classroom factors at several levels. For OTL, this matters

because students of similar family resources. may still meet different topic ranges, different amounts of mathematics time, Could you please elaborate or clarify what you mean by "Or both"? I would be happy to assist you further.

Bokhove's (2022) analysis of TIMSS 2019 also found cross-regional differences in reported Grade 8 instructional practices. The point is not to divide mathematics. teaching into fixed East-West models. It is to recognise that teacher-reported. practices and the opportunities they create should be interpreted in their Curriculum context.

The OTL literature does not support reducing instructional opportunity to a single questionnaire variable. Coverage is important because students cannot. expected to answer well on content that they have not had a reasonable chance Meanwhile, OTL encompasses task quality and disciplinary discipline. Climate, Educator Expertise, Feedback, and Lesson Time Utilization and Ham (2021), for instance, found that links between OTL and mathematical Literacy differed across types of mathematical tasks. Guo and Liao (2022) likewise reported connections between OTL, mathematics performance, mathematics anxiety, and issues related to problems to solve. These studies indicate that. opportunity isn't solely about the availability of it but also about the quality and the way it is presented. Math activities that a teacher makes possible in the classroom.

For In this study, coverage and instructional time are analyzed independently. Students have been taught a reasonably wide set of topics. Time asks. How much scheduled exposure they have to mathematics. They may be connected. However, they are not identical. A class can still be scheduled to have additional lessons outside of the regular class time. Repeat a narrow part of the curriculum. Another class can move across many subjects. Topics too quickly for explanation, practice and consolidation. distinction fits a curriculum-and-teaching perspective and avoids treating more Time is always better time.

1.2. Content coverage, time, and mathematics achievement

Research using international assessment data has produced reasons to expect a positive relationship between content coverage and achievement, but it also shows why Such a relationship should not be exaggerated. According to Daus and Braeken (2018). that country comparisons in TIMSS can be sensitive to classroom-level They remind researchers of achievement differences in OTL. Can partly reflect what students were able to experience. Yang Hansen (2018) further showed that mathematics curricula have not simply The situation gradually became uniform, though international evaluations employed similar frameworks. Thus, the same assessment score can sit within different curriculum traditions And instructional sequences.

Teacher and instructional factors may also shape the value of time. Akiba et al. (2007) linked national achievement patterns to teacher quality and opportunity gaps, while Blömeke et al. (2016) argued that instructional quality is an important route through which teacher characteristics can matter for student outcomes. More recent evidence has focused on the student experience of teaching. Liu et al. (2024), using PISA data, reported cross-national associations between student-perceived instructional quality and mathematics achievement, although those associations varied across countries. Wang, Liu, and Leung (2022) found that disciplinary climate and OTL were related to mathematics achievement in a doubly latent multilevel model. Together, this literature suggests that instructional time should be considered in its classroom context. Extra minutes may have little value if they repeat already-mastered work or if the classroom is difficult to manage.

There is also a methodological reason to be cautious. Studies of international assessment data are generally observational. Students are not randomly assigned to teachers, courses, or amounts of mathematics instruction. Schools may allocate additional time to students who are struggling, while other schools may be able to move more quickly because students enter with stronger preparation. A positive, null, or negative raw association between time and achievement can therefore reflect selection as well as instruction. Wang, Perry, Malpique, and Ide (2023) reached a similar conclusion in their systematic review of factors predicting mathematics achievement in PISA: the direction and size of associations need to be interpreted within the design and level of analysis.

1.3. Gap and research questions

The present study contributes by using the new TIMSS 2023 Grade 8 database and by examining teacher-reported coverage and weekly time in the same model. It focuses on four mathematics content areas that correspond closely to the TIMSS framework: number, algebra, geometry/measurement, and data/probability. This makes it possible to ask not only whether average coverage matters, but also whether particular coverage domains show different associations. The study is aligned with research on mathematics curriculum, classroom teaching efficiency, and educational assessment. It does not claim that teachers can raise achievement simply by increasing hours or by reporting more topics. Rather, it asks whether these OTL indicators remain related to achievement after basic student background differences and system-level differences are taken into account.

Three questions guide the analysis:

- (1) How much do content coverage and weekly mathematics instructional time vary in the linked TIMSS 2023 Grade 8 sample?
- (2) Are composite content coverage and instructional time associated with mathematics achievement after adjustment for home educational resources, student sex, and education-system differences?
- (3) When content coverage is separated into number, algebra, geometry/measurement, and data/probability, which domains show the clearest adjusted associations with achievement?

2. Research method

2.1. Design and data source

The study used a cross-sectional secondary analysis of the TIMSS 2023 international public-use database. TIMSS suits the research question because it combines comparable mathematics assessment results with student and teacher questionnaires. According to the official user guide, the student-teacher linkage file has one entry for each student-teacher combination and provides the information needed to attach teacher context data to the appropriate student record (Fishbein et al., 2025). This is important in Grade 8 data, since one student may be linked to more than one subject teacher. Using the official linkage is more defensible than trying to connect teacher and student records through a class code alone.

Three Grade 8 files were needed: the student background file, the mathematics teacher file, and the student-mathematics-teacher linkage file. All three types were available for 47 education systems in the public archive. After the files were joined through the official teacher-link identifier and the valid-data rules were applied, the analytic sample contained 112,827 student-mathematics-teacher links from 46 systems. These records represented 111,954 unique students in 8,259 schools. There were 873 more links

than students. The difference is small, but it is reported because the analysis is organised around a student-teacher link, not around an independent student only.

The data are public-use and contain no information that identifies individual students or teachers. The analysis did not involve contact with participants or collection of new personal data. It was conducted as an educational secondary-data study using the official codebook and user guide.

3. Measures

3.1. Mathematics achievement

The outcome was Grade 8 mathematics achievement. TIMSS provides five plausible values for each student instead of one fixed test mark. These values are intended for estimating relationships at the population level; they should not be read as exact measures of one student's achievement (Fishbein et al., 2025). For this reason, all five mathematics plausible values were analysed separately and then combined. This is preferable to choosing one plausible value without a reason and losing part of the uncertainty built into the assessment design.

3.2. Content coverage

The main OTL measure came from four mathematics-teacher indicators: the percentage of students taught number, algebra, geometry/measurement, and data/probability topics. Every indicator ranged from 0 to 100. Composite coverage was the simple mean of these four percentages and was calculated only when a teacher had a valid response for every domain. This decision matters. A score calculated from one or two completed domains would give a misleading impression of broad curriculum coverage. A second model included the four domains separately so that the composite result could be checked rather than assumed.

3.3. Instructional time

Mathematics instructional time was the teacher-reported number of hours per week spent teaching mathematics. It was treated as a continuous variable. A squared term was included because the benefit of added time may diminish when a class already has substantial weekly mathematics time. The quadratic term was included as a descriptive functional-form test, not as an attempt to identify an optimal national timetable.

3.4. Control variables

Student sex and the TIMSS home educational resources scale were included as student-level controls. Home educational resources is an established indicator of family learning resources and educational background in TIMSS. It was included to reduce, although not remove, confounding from differences in students' home learning conditions. Education-system fixed effects were included to compare students and teacher links within systems rather than allowing between-system differences in curriculum, wealth, language, or assessment conditions to drive the main coefficients.

3.5. Data preparation and analysis strategy

Records were kept when they had a mathematics teacher link, a positive mathematics-teacher weight, valid values for all four coverage domains, valid weekly mathematics time, both controls, and all five mathematics plausible values. Invalid and omitted codes were recoded as missing on the basis of the TIMSS codebook before this rule was used. The linked records were weighted with the mathematics-teacher weight

supplied in the linkage file. A pooled international regression can easily be dominated by a large system, so weights were rescaled to sum to one within each system. As a result, every included system made the same total contribution to the analysis, while the original teacher weights continued to distinguish records within that system.

The following weighted model was estimated for each plausible value:

$$Y_{ij} = \alpha + \beta_1 C_{ij} + \beta_2 T_{ij} + \beta_3 T_{ij}^2 + \beta_4 H_{ij} + \beta_5 F_{ij} + \gamma_j + \varepsilon_{ij}$$

where Y_{ij} is mathematics achievement for a student-teacher link, C_{ij} is standardised content coverage, T_{ij} is standardised weekly instructional time, H_{ij} is standardised home educational resources, F_{ij} is the female indicator, and γ_j represents education-system fixed effects. Standardising continuous predictors means that their coefficients can be compared as associations for a one-standard-deviation difference. The domain model replaced composite coverage with the four standardised domain indicators and retained both time terms and the controls.

Weighted least squares produced the point estimates. Standard errors were calculated with a school-clustered sandwich estimator so that links from the same school were not treated as fully independent. The five sets of estimates and covariance matrices were combined using Rubin's rules for plausible values. This follows the main logic of TIMSS secondary analysis, but it is not a full reproduction of the official TIMSS jackknife replication procedure. The inferential results should therefore be treated as robust pooled-model approximations. The official archive, codebook, and the accompanying analysis script allow the analysis to be reproduced.

4. Data analysis

4.1. Descriptive results

Table 1 gives an overview of the weighted analytic sample. Mean composite coverage was 79.67% (SD = 16.27). This does not mean that every student completed exactly four-fifths of an intended curriculum. It is a teacher-reported summary of the percentage of students taught topics in the four TIMSS content areas. The four areas were not covered evenly. Number coverage was very high (97.07%), while algebra coverage was lower (69.25%). Geometry/measurement was 79.91% and data/probability was 72.43%. This is one reason to look beyond a single coverage average: the average can conceal clear differences in the topics that classes reach.

Teachers reported an average of 3.87 mathematics hours per week (SD = 1.76). The range was broad, from around 0.02 to 16.67 hours. Very low and very high responses may partly reflect local ways of reporting a timetable, not only genuinely unusual school schedules. This is another reason why the time coefficient should not be turned into a direct policy rule. The equally weighted mean mathematics achievement score, based on the average of five plausible values, was 438.82 (SD = 98.21). Home educational resources averaged 8.75 (SD = 1.01).

Table 1. Weighted descriptive statistics for the analytic sample.

Variable	Weighted mean	Weighted SD	Minimum	Maximum
Average content coverage (%)	79.67	16.27	0.00	100.00
Mathematics instructional hours per week	3.87	1.76	0.02	16.67
Home educational resources (scale)	8.75	1.01	4.30	9.66
Mathematics achievement (mean of five PVs)	438.82	98.21	59.94	814.29

Note. N = 112,827 student-mathematics-teacher links from 111,954 unique students. Weights are normalised within education systems so that each system has equal total analytic weight. PV = plausible value.

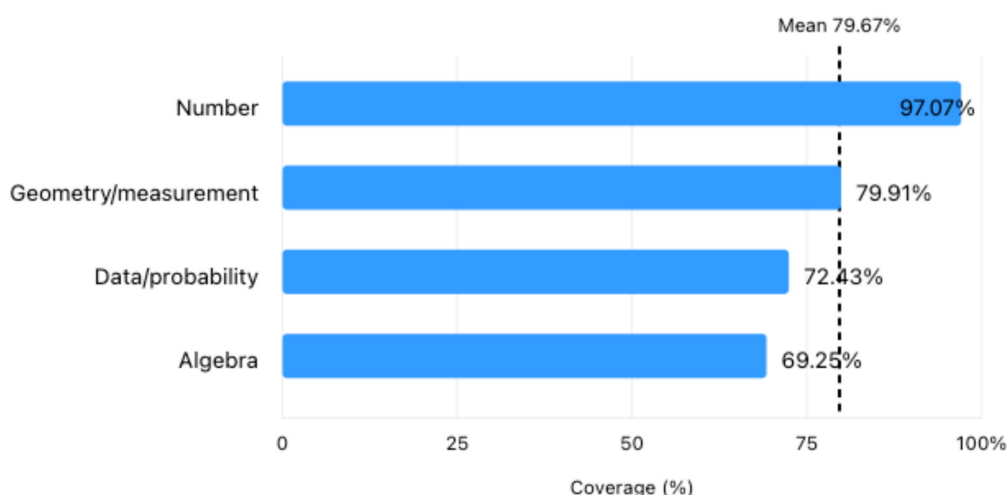


Figure 1. Content coverage.

4.2. Adjusted associations with mathematics achievement

Table 2 presents the pooled regression results. In Model 1, which uses composite coverage, the coverage coefficient is positive and statistically clear. A one-standard-deviation difference in coverage, or 16.27 percentage points, was associated with a 4.06-point higher mathematics score ($SE = 1.06$, $p < .001$), after the controls and system fixed effects were included. The association is modest beside the overall variation in students' scores. Even so, it remains after comparisons are made within education systems and home educational resources are taken into account. This pattern is in line with the OTL argument that a wider range of taught content can give students more relevant preparation for a mathematics assessment.

At the mean level of instructional time, the linear coefficient was positive but not statistically clear ($b = 1.50$, $SE = 1.12$, $p = .181$). The squared term was small and negative ($b = -0.47$, $SE = 0.20$, $p = .021$). Together, the two terms describe a shallow concave pattern, not a large linear time effect. The fitted curve has a turning point at about 6.7 hours per week, but the predicted difference between mean time and this point is only around 1.2 score points. The calculation describes the shape of this model; it does not show that 6.7 hours is an ideal timetable. A safer reading is that the association is compatible with diminishing returns and does not support the simple claim that more mathematics hours will reliably raise achievement.

Home educational resources had the largest adjusted coefficient among the non-system predictors. A one-standard-deviation difference was associated with about 13.18 additional score points in Model 1 ($SE = 0.46$, $p < .001$). Female students scored about 7.70 points lower than male students in this pooled and adjusted model ($SE = 1.00$, $p < .001$). These control estimates are not the focus of the paper, and their meaning may differ by system. They are included to show that the OTL coefficients are estimated in a model that considers two basic sources of student-level variation.

Model 2 looks at the coverage domains separately. Number coverage was positively associated with achievement ($b = 4.24$, $SE = 0.82$, $p < .001$). The algebra estimate was smaller and only borderline ($b = 2.16$, $SE = 1.10$, $p = .049$). The coefficients for geometry/measurement ($b = 0.67$, $SE = 1.00$) and data/probability ($b = 0.16$, $SE = 0.80$) were not statistically clear. Adding the domains made very little difference to both time terms. In this linked sample, the composite association therefore seems to come mainly from variation in number coverage. That does not mean that number is educationally more important than the other topics.

These estimates are conditional correlations based on teacher reports, and those reports are also shaped by curriculum sequence and local assessment practice.

Table 2. Weighted pooled associations with Grade 8 mathematics achievement.

Predictor	Model 1: Composite coverage b (SE)	Model 2: Content domains b (SE)
Composite content coverage	4.06 (1.06)	—
Number coverage	—	4.24 (0.82)
Algebra coverage	—	2.16* (1.10)
Geometry/measurement coverage	—	0.67 (1.00)
Data/probability coverage	—	0.16 (0.80)
Instructional hours per week	1.50 (1.12)	1.45 (1.12)
Instructional hours squared	-0.47* (0.20)	-0.48* (0.20)
Home educational resources	13.18 (0.46)	13.13 (0.46)
Female	-7.70 (1.00)	-7.71 (1.00)
Education-system fixed effects	Yes	Yes
Student-teacher links	112,827	112,827
School clusters	8,259	8,259

Note. Coefficients for continuous predictors are based on standardised variables. Results are pooled across five mathematics plausible values using Rubin's rules. Mathematics-teacher weights are normalised within system; standard errors are clustered by school. $p < .05$. $p^* < .001$.

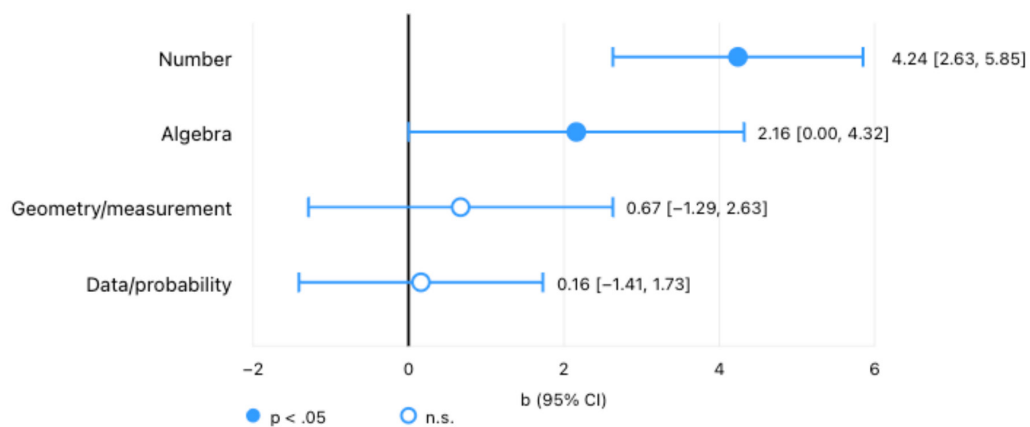


Figure 2. Domain coefficients.

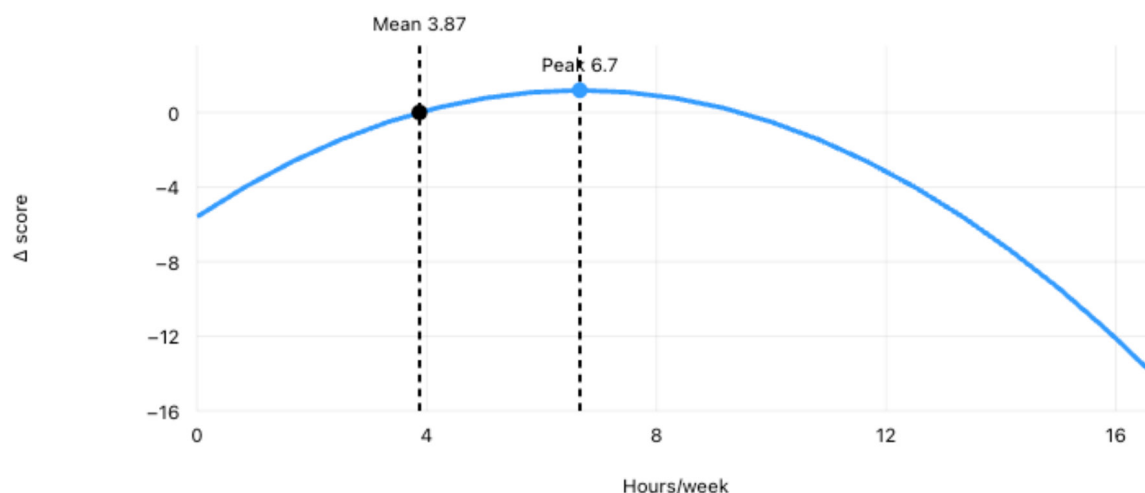


Figure 3. Instructional-time curve.

The regression results answer a limited question. They show that, in the selected TIMSS 2023 data, teacher-reported coverage was associated with achievement after the included adjustments. They do not show that increasing coverage by 16 percentage points would cause every student's score to rise by four points. Teachers may report wider coverage when their students already learn more quickly, and schools may organise the curriculum differently for reasons that the available variables do not capture. The time result is particularly sensitive to this problem. Schools can add lessons as a response to low attainment, while high-attaining students may need less scheduled time to meet the same curriculum goals.

5. Discussion

This study considered two related, but different, parts of mathematics OTL in TIMSS 2023: teacher-reported content coverage and weekly math time. The result was a positive association between broader composite coverage and Grade 8 mathematics achievement after home educational resources, sex, and education-system fixed effects were added. The coefficient is not big. However, it stays positive across the five plausible values and remains statistically obvious when standard errors are clustered by school. When inputting the coverage areas, number had the most significant correlation. Algebra, which had shown a relatively low score, and the other two domains did not show a statistically significant difference.

The Coverage finding supports curriculum-and-teaching perspective of OTL. Efficiency does not equate to rushing through a syllabus. Students still need a realistic opportunity to meet the knowledge and when a topic is omitted, the curriculum expects them to use. covered in a rush, or reached by only part of the class, later differences in achievement are not surprising. The high mean for number coverage and the positive number coefficient may reflect the foundational place of number in Though the research cannot prove that number teaching is an issue, it is still possible. More important than teaching algebra, geometry, or data. The topics are related in the classroom. a curriculum, and teachers in different systems may report their topic coverage In different ways.

The result for time gives an important qualification. In the adjusted model, more. weekly mathematics time was not linked to a large or clearly linear increase in achievement. Although the negative squared term was statistically significant, it was. The curve was, in fact, very gentle. Hence, time shouldn't be given as a consideration. separate resource that can simply be added without asking what happens during

Extra periods may achieve nothing if interrupted, practical, or practical. mainly for routine repetition or introduced because a class already has low On the other hand, a carefully designed lesson can allow a small timetable to be effective. Explanation, practice, discussion, and feedback are more effective when they are interconnected. view is consistent with work that places instructional quality and classroom conditions alongside the time available for learning (Blömeke et al., 2016; Liu. et al., 2024).

For curriculum work and teacher development, a practical response is to monitor Coverage as a diagnostic rather than as merely a target by itself. department leaders can use curriculum maps or simple topic trackers to check whether classes are reaching all major content areas and whether some students are falling behind when a topic begins. Such information is better used to. Support professional discussion rather than create a high-stakes compliance rule. teacher may need to spend longer on a difficult topic, and that can be entirely The evidence does not indicate that all teachers have to attain equal success, though it may suggest that teachers can be successful at different levels. percentage on the same date. It does implicate unexplained coverage gaps. In particular, for foundational content, such situations can be quite common.

The Research significance also extends to educational assessment. assessments are often used to compare outcomes, but OTL indicators help explain why identical achievement targets do not represent identical learning History. Including teacher-reported coverage and time in secondary analyses. makes the curriculum dimension more visible. At the same time, teacher. Questionnaire data should be interpreted carefully. A percentage reported by an item in a questionnaire might not always accurately represent the entire population, as it could be derived from a biased sample or could be misinterpreted by the respondents. Therefore, while percentages can provide helpful insights, they should be critically evaluated within the context of the study and not regarded as definitive answers. teacher is not a direct observation of student participation, lesson quality, It is an indicator of the conceptual understanding nonetheless, though the knowledge is partial. Future TIMSS-based research can reinforce this study. combining teacher reports with student reports of instruction, textbook analysis, Curriculum documents, or lesson observations, where available.

The To begin with, the layout should remain as close as possible to the research outcomes. Student controls, system fixed effects, weights, cross-sectional study. school-clustered standard errors reduce some problems, but they do not remove Second, the complete-case rule reduced the 47 systems. with the required files to 46 analytic systems, which may change the composition of the original TIMSS samples. Third, the pooled model. This purposefully adds equal weight to the total of each system. Hence, it is user-friendly. describe a cross-system pattern, but it is not a population-weighted global Fourth, the standard errors are robust clustered at the school level. not a full replication-based implementation of the TIMSS sampling-variance Ultimately, coverage was indicated by four reported percentages. data cannot show the depth, quality, timing, or cognitive demand of teaching Within a content domain.

These Constraints also indicate avenues of future research. estimate multilevel models separately within systems, test whether OTL associations differ by home resources, or compare teacher-reported coverage It would help to also look at the national curriculum expectations. whether the relationship between time and achievement changes when the quality Such work would consist of clarification, management of classroom order, or nature of the assignment. move from the question of how much time students receive to the more Educationally meaningful question of what they are able to do during that time.

To conclude, the TIMSS 2023 results show a modest but consistent association between teacher-reported breadth of mathematics coverage and Grade 8 Achievement in the included systems. Weekly instructional time doesn't exhibit a weekly achievement. strong linear relationship after coverage and student background are The guarded message is that there may be better mathematics opportunities. depend less on adding time by itself and more on whether that time gives Students have access to a well-defined selection of significant content.

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