Independent analysis of the relationship between Sparx Maths and maths outcomes

Technical Report

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This document has been prepared for Sparx UK however it reflects the views only of the authors

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Introduction

In line with their commitment to enhancing learning through a scientifically proven approach, Sparx[1] providers of Sparx Maths – an electronic, personalised learning platform developed to aid the delivery of lessons and homework for Key Stage 3 and GCSE students (ages 11 to 16) – commissioned RAND Europe and the University of Cambridge to independently assess the relationship between use of Sparx Maths and student achievement in maths. This report outlines the findings in detail, along with the underlying methodological approach. A shorter account can be found in the key findings report.[2]

Background

The use of digital tools and practices in education – also known as Educational Technology (EdTech) – is undergoing a period of unprecedented growth in the UK, with schools increasingly looking to EdTech to support teaching and learning in the classroom.[3] In 2019, the Department for Education signalled its commitment to such technologies through its EdTech Strategy, seeking, for instance, to reduce teacher marking workload and increase accessibility for students with special educational needs and disabilities.[4] In recent months, this growth has been intensified due to the unprecedented need to move to online modes of teaching, as a means of containing the spread of COVID-19. EdTech is noted to be at the fore of this adaptation and plays a role in hastening the digitisation of education.[5]

Evidence from over 40 years of research has shown the potential for EdTech to support learning, when implemented effectively.[6] For instance, reviews by the Education Endowment Foundation (EEF) suggest that the use of technology in maths is usually more effective when simulations, scaffolding and/or intelligent tutoring systems are used.[7] Such technology is also evidenced to be most effective where it supplements, rather than replaces, other forms of instruction.[8]

Sparx Maths is an electronic, personalised learning platform developed to aid the delivery of lessons and homework for Key Stage 3 and GCSE students (ages 11 to 16) in the UK. The platform contains over

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[1] https://sparx.co.uk/

[2] https://www.educ.cam.ac.uk/research/workingpapers/

[3] RS Components. 2020. 'The EdTech Report 2019/20.' Available at https://uk.rs-online.com/web/generalDisplay.html?id=did-you-know/the-edtech-report

[4] Department for Education. 2019. *Realising the Potential of Technology in Education: A Strategy for Education Providers and the Technology Industry.* Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/791931/DfE-Education_Technology_Strategy.pdf

[5] Schmidt J. T. & M. Tang. 2020. 'Digitalization in Education: Challenges, Trends and Transformative Potential.' In: Harwardt M., P. J. Niermann, A. Schmutte & A. Steuernagel (eds) *Führen und Managen in der Digitalen Transformation*. Springer Gabler, Wiesbaden. https://doi.org/10.1007/978-3-658-28670-5_16

[6] Education Endowment Foundation. 2019. *Digital Technology. Teaching & Learning Toolkit.* As of 14 December 2020: https://educationendowmentfoundation.org.uk/pdf/generate/?u=https://educationendowmentfoundation.org.uk/pdf/toolkit/?id=134&t=Teaching%20and%20Learning%20Toolkit&e=134&s=

[7] *Ibid.*

[8] Hattie, John & Gregory Yates. 2013. *Visible Learning and the Science of How We Learn.* London: Routledge.

38,000 questions and over 9,000 video tutorials, delivered to students through a tailored and personalised learning platform. Sparx Maths strives to be an evidence-based system, developed in line with published evidence of effective approaches in education.[9]

There are currently two versions of Sparx Maths: a *classroom plus homework* version and a *homework only* version. In both versions, students receive personalised homework assignments of appropriately challenging questions delivered through a spaced repetition algorithm delivered in interleaved order. Students receive instant feedback and can access help through support videos, and teachers receive feedback from homework. For the *classroom plus homework* version, teachers also receive lesson plans and teaching materials. In addition, as students complete their classwork, teachers receive real-time insights, and can interact with the whole class or individual students throughout the lesson, controlling the progression of the lesson. In practice, the implementation of the two is similar, with schools integrating either version into their teaching.

Sparx recommends that schools use Sparx Maths consistently and repeatedly over time (see Theory of Change, Appendix A) to achieve impact. Ideally, this equals one hour of homework every week (39 hours over an average school year) for both versions, in addition to regular use of the classroom component in the *classroom plus homework* version (up to four hours every week). In line with this, Sparx helps schools and trusts to actively monitor weekly implementation at school and class level by reviewing homework and lesson completion rates, and supporting schools with best practice suggestions if usage falls below recommended levels.

Evaluation methodology

Researchers from RAND Europe and the University of Cambridge undertook an analysis of data collected by Sparx from 3,956 Year 7 and Year 8 students across 14 schools in the UK, following a study plan published ahead of the analysis.[10] Schools included a mix of those that used the *classroom plus homework* version and the *homework only* version. Schools were also mixed in their familiarity with Sparx Maths, with some schools having used it previously, while others had only recently started implementing it in January or Easter of the same year (i.e. 2019). Students included those who had access to Sparx Maths and spent time on the platform, those who had access to it but spent no time on the platform, and those who had no access to it at all.

RAND Europe supported the development of a Sparx Maths Theory of Change to provide a shared understanding of how Sparx impacts on learning outcomes of interest (Appendix A). Researchers asked the Sparx team to identify key elements of Sparx Maths delivery and contextual factors, as well as isolate key impacts and outcomes. This report provides an overview of our findings, starting with a review of the methodological approach, followed by the results of the analyses.

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[9] Nawaz, Sidra, Stephen Welbourne & Georgie Hart. 2019. *Why Sparx Maths Works: Evidence-based Design*. As of 14 December 2020: https://sparx.co.uk/wp-content/uploads/2019/06/Why-Sparx-Maths-works.pdf

[10] http://www.educ.cam.ac.uk/research/projects/sparx/SparxStudyPlan30072020.pdf

This section outlines the research methodology, as pre-specified in the published study plan.[11] Minor changes to the analytical approach emerging from data-driven limitations are explicitly outlined wherever relevant.

Research questions

Primary research question

RQ1: What is the relationship between usage of Sparx Maths and student achievement in maths for Year 7 and Year 8 students?

Further research questions

RQ2*:* To what extent is time spent on Sparx Maths associated with student achievement in maths?

RQ3: To what extent is Sparx Maths associated with student achievement in maths differently, depending on their demographic and socio-economic characteristics?

Sample

Data were collected from a set of 14 UK schools that routinely use Sparx Maths for Year 7 and/or Year 8 students. A total of 3,956 students in Year 7 and Year 8 provided data, including some who were in cohorts that did not use Sparx Maths at all (Year 8), and some who had engaged with Sparx Maths for varying lengths of time, between a few months and two years. The average sample characteristics are illustrated in Table 1:

Table 1. Demographic characteristics of the sample

Year group	Year 7	Year 8	Missing
	40.1%	59.9%	0.0%
Gender	Male	Female	Missing
	46.4%	45.2%	8.4%
Eligibility for free school meals (FSM)	Eligible	Not eligible	Missing
	38.5%	61.0%	0.5%
English as additional language (EAL)	EAL	Non-EAL	Missing
	5.4%	94.1%	0.5%

The proportion of students eligible for Free School Meals (FSM) in the sample is substantially higher than the national averages reported in the National Pupil Database (NPD) for secondary school students aged 11 (16.2%), 12 (15.5%) and 13 (15.0%). This suggests that the sample of schools in this dataset has a higher proportion of socio-economically disadvantaged students than the national average.

At the school level (and in some instances at class level), available data also included a range of background characteristics (averages per schools), such as the proportion of students eligible for free school meals (FSM) and the proportion of students with English as an additional language (EAL).

[11] *Ibid.*

Sparx usage data

Data for this analysis were provided to RAND by Sparx and represent data that had been collected by Sparx as part of their own internal evaluation. At the student level, and in addition to the background characteristics identified above (year group, gender, FSM eligibility), the data included Sparx Maths usage measures and attainment outcomes.

Sparx Maths usage data were provided in the form of usage records in relation to Sparx Maths, with data on students who did not use Sparx Maths (which later served as a comparison group). This allowed for the operationalisation of Sparx usage in two separate ways. First, a binary variable identified access to either of the Sparx Maths versions. A total of 60.82 per cent of the sample had access to Sparx Maths, split across the *classroom plus homework* version (40.80 per cent) or the *homework only* version (20.02 per cent). Given overlap between how these two versions are routinely used by schools, they are considered together in the later analysis (i.e. students with access to either Sparx Maths version are pooled for the analysis and considered with reference to students without access to any Sparx Maths version). Access to either of the Sparx Maths versions does not, however, imply that each individual student had actively engaged with Sparx Maths.

Second, a continuous variable identified time (in hours) of Sparx Maths usage. The distribution of this latter variable showed students who used Sparx Maths on average used it for 36.9 hours, ranging between 0 hours (no use at all in a *classroom plus homework* or *homework only* version where the product was available) and just over 256 hours. This variable was considered more in line with actual Sparx usage (as opposed to access) as it measures time students spend on the platform.

Sparx recommends that for an effect on maths outcomes to be visible after one full academic year, usage should be of one hour per week. Given the average length of the school year at 39 weeks, when reporting the association between Sparx usage, we also report the estimated change in mathematics outcomes associated with 39 hours' usage of Sparx Maths (of either version) to estimate the effect of a full year's 'dosage'. Just under 20 per cent of the sample of students using Sparx Maths used it for 39 or more hours.

An alternative measure of access to Sparx Maths provided to RAND was the total number of days between individual students' first use of the platform and the day that they completed the Progress in Understanding Mathematics Assessment (PUMA) – the outcome test used by the Sparx Maths team. Importantly, the summary statistics shown in Table 2 indicate that among those students who had access to Sparx Maths (even if they did not use it), the number of days between their first use and the outcome assessment was highly variable, as indicated by the wide range and standard deviation. This was not used in any of the analyses but highlights the variation in when schools registered students and the outcome assessment.

Table 2. Summary statistics for time between students' first use of Sparx Maths and PUMA assessment

	N= (%)	Mean (SD)	Range
Time (in days) between first Sparx Maths use and assessment	2,393 (60.5%)	286.8 (175.8)	2.6–660.6

Note: The table above presents information only on the subset of students who had access to Sparx Maths, i.e. students where time between first Sparx Maths use and assessment was not 0.

Attainment data

Data were also available on two sets of academic measures: students' key stage (KS) 2 (age 11) outcomes (completed prior to Sparx Maths being implemented) and students' maths scores collected via the written PUMA test[12] (completed as an outcome measure). KS2 outcomes are completed by all pupils in England at the end of their primary school education (Year 6). They are administered by teachers, but math tests are independently marked. Both are reliable and valid measures of maths attainment. An imputed KS2 was available, giving 100 per cent coverage of the sample. This imputed variable was used in the analysis as a baseline attainment measure and was also used to derive a separate variable that identified the lowest-attaining students (at KS2) for use in subsequent sub-group analyses.

The PUMA was available in several different variants, including raw marks and standardised scores. PUMA standardised scores were used for the main outcome measure. As stated in the study plan, it was initially planned to use PUMA age-corrected scores to serve as a robustness check for the main outcome measure. However, these data were not available due to discrepancies identified by the Sparx team in the PUMA-specific calculations of age-adjusted scores.

An imputed variable for the PUMA maths outcome was also available. However, to ensure the robustness of the analysis, the non-imputed version of this outcome variable was used throughout the analysis.

Also available in the data was a forecasted GCSE grade, derived from a percentile mapping of the PUMA standardised scores onto the GCSE scale (from 1–9). Figure 1 illustrates this. To facilitate interpretation, the forecasted GCSE grade was used to express the effect size of the relationship between Sparx Maths (time) and mathematics outcomes; we have done this in full GCSE grade increments, despite the fact that the percentile ranking mapping has resulted in a continuous forecasted GCSE score variable.

Figure 1. Scatter plot: PUMA standardised scores and forecasted GCSE grades

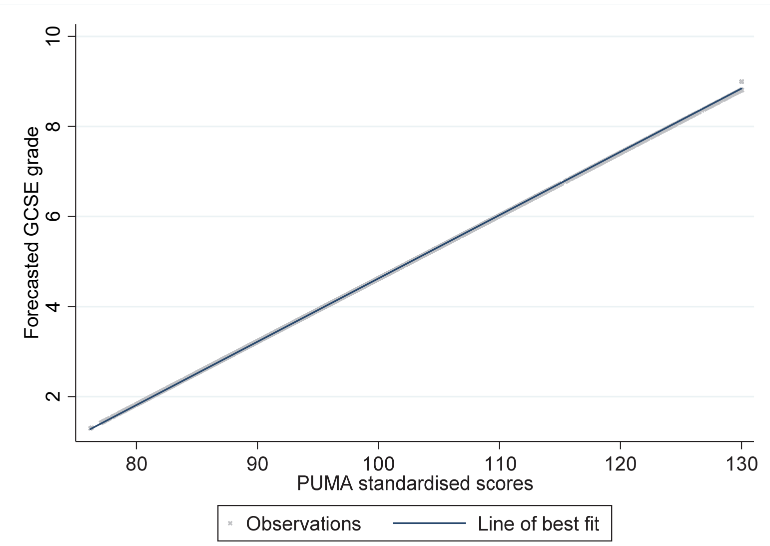


Table 3 below provides descriptive statistics for all variables of interest.

[12] https://www.hoddereducation.co.uk/subjects/assessment/assessment-series/puma-at-key-stage-3

Table 3. Summary characteristics of maths measures (prior attainment and outcome)

	Proportion sample with available data	Mean (SD)	Range
KS2	95.2%	103.4 (6.6)	80–120
KS2 imputed (used in analysis)[13]	100%	103.2 (6.6)	80–120
PUMA standardised scores	93.2%	102.5 (14.1)	76–130
Forecasted GCSE grade	93.0%	5.0 (2.0)	1.3–9.0

Note: Range of tests is not comparable across Year 7 and Year 8 tests, as they are separate tests.

Analysis

Missing data

Missing data and the missing pattern may impact on the robustness of the findings. Overall, the proportion of missing data was low, between 0 per cent and 8.4 per cent for non-imputed variables; imputed variables displayed no missing data. A logistic regression model (Appendix B1 – Missing data analysis) was used to understand if missingness in the main maths scores outcome variable was associated with any other student characteristics. This model used the following predictors: gender, FSM eligibility, English as additional language (EAL) status and month of birth. The results only showed significantly higher odds of a missing maths outcome for students receiving FSM compared with those who do not. Therefore, to ensure a systematic treatment of all control variables and include observations with missing data in the analysis, separate categories for each variable displaying missing values were generated (e.g. FSM eligible: yes/no/unknown or missing) and subsequently used in the analysis.

Primary outcome analysis

In response to the primary research question (RQ1), a multi-level (random effects) model was estimated, with: maths achievement as the outcome variable (standardised scores on PUMA, as above), KS2 scores to control for prior attainment (imputed variable, as above) and control variables at the student level including all socio-demographic data such as gender, FSM eligibility, EAL status, etc., as above.

The multi-level analytical approach accounted for the nested nature of data, with students in classes in schools and is a widely used analytical approach.[14] With a small number of schools in the sample, the between-school proportion of variance was very small (4.5 per cent only), resulting in only the class clustering being used in the multi-level models (between-class proportion of variance is 60 per cent).

[13] To avoid excluding students whose KS2 scores were missing, an imputation process was carried out by the Sparx team, resulting in KS2 scores for all 3,956 observations in the sample.

[14] Gelman, A., J. Hill & M. Yajima. 2012. 'Why We (Usually) Don't Have to Worry About Multiple Comparisons.' *Journal of Research on Educational Effectiveness* 5(2): 189–211.

As a robustness check, the study plan set out to substitute PUMA scores with predicted GCSE grades (derived from a combination of the standardised PUMA score and prior distributions of GCSE grades). We provide this throughout the analysis, wherever relevant.

The 'treatment' variable was Sparx Maths usage, operationalised using the two variables (binary and continuous) as outlined above.

All analyses were conducted in Stata version 15 and onwards. Full statistical results for all models reported here are included in Appendix B – Full model specifications.

Subgroup analyses

Additional subgroup analyses were conducted to assess the impact of Sparx Maths on different students (RQ3). These subgroups were chosen in consultation with Sparx Maths as the subgroups that Sparx believed would most benefit from Sparx Maths. The main model used in the primary outcome analysis was respecified to include respectively interaction terms to identify the specific association between Sparx Maths and student maths outcomes for students with EAL and those eligible for FSM. An analysis that looked at the relationship between Sparx Maths and maths achievement for students with lower prior attainment was also conducted. To create this comparison, a distribution of KS2 data was used to generate a binary variable identifying students in the bottom 25 per cent of the prior attaining distribution. This bottom quartile included 989 students, all with KS2 scores below 99.64 (against a full KS2 score distribution ranging from 80 to 120). This variable was then interacted with the continuous measure of time spent (in hours) using Sparx Maths as for the other sub-group analyses above. In this subgroup analysis, the main model used in the primary outcome analysis was respecified to omit the continuous variable for KS2 standardised scores, given that the interaction term included a binary variable that already used the distribution of KS2 data to differentiate those scoring in the lowest quartile from the rest of the sample.

We note that across all these models, a substantial amount of variance at both individual and class level remains unexplained by the models, suggesting that a variety of (currently unobserved factors) may be at play. These could include aspects unrelated to the intervention (e.g. parental input), or factors related to Sparx Maths (e.g. cognitive engagement during Sparx Maths usage).

Exploratory analyses – establishing a stronger counterfactual with propensity score matching (PSM)

The possibility of establishing a stronger (though not perfect) counterfactual was explored by using propensity score matching (PSM). This approach used data from a non-random-allocation research design to estimate the effects of treatment (in this case, participation in Sparx Maths) on outcomes, by using available data to produce quantifiably similar pairs of students who differed only in their use of Sparx Maths (i.e. one student in the pair had access to Sparx Maths and the other did not).

A major limitation of this approach to pairing students is that it is possible that the intervention group will include students who have not used Sparx Maths (despite having access to it generally speaking). Comparing this intervention group with the control group of students who have never had access to Sparx Maths will result in a conservative estimate of the impact of Sparx Maths on maths outcomes. However, as shown in Table 4, only a small proportion of students in the intervention group (i.e. with general access to Sparx Maths) were observed to have had no engagement with it whatsoever (i.e. 0 hours).

An alternative matching approach would have been to use the continuous variable for time spent (in hours) using Sparx Maths to derive a binary variable (akin to a treatment variable) identifying a (potentially arbitrary) high level of Sparx Maths usage. Given the evidence above showing the variability in the time spent using Sparx Maths, this approach would not reflect the realities of on-the-ground Sparx implementation. Consequently, while the approach used to match students in this study comes with some limitations, it is the most appropriate method given the sample characteristics.

Table 4. Usage of Sparx Maths for students with access to the intervention (either version)

Access to Sparx Maths	N	%
No hours logged in Sparx Maths (zero hours usage of Sparx Maths)	9	0.4%
Hours logged in Sparx Maths (at least some usage of Sparx Maths)	2,397	99.6%
Total	2,406	100.0

Results

Primary outcome analysis

The first model (Table 5) explores the relationship between access to Sparx and maths outcomes, controlling for the full set of background characteristics (see Appendix B2 – Primary outcome analysis). That is, the model looks at the relationship between the availability of Sparx Maths and maths outcomes, regardless of whether individual students in the intervention group have engaged with Sparx Maths. The reference category is 'no access to Sparx Maths'.

The results point to no evidence of statistically significant differences in maths outcomes between the intervention group with access to Sparx maths and the comparison of students without access to Sparx Maths, all other background characteristics being held equal.

Table 5. Relationship between access to Sparx and maths outcomes

Outcome: PUMA standardised scores	Coef.	Std. Err.	P>z	[95% Conf. Interval]	
Access to Sparx Maths	-0.508	1.032	0.622	-2.531	1.515

Note: Number of students, N=3,686. Number of classes, N=160.

Table 6 explores the relationship between Sparx Maths usage (in hours) and maths outcomes (PUMA test scores, as above) where usage is total time spent on the platform, including time working on set tasks and time watching educational videos. The results of this model indicate that time spent using Sparx Maths was associated with higher scores on PUMA and that this is statistically significant, albeit with a relatively small effect size. Each additional hour spent using Sparx Maths was associated with an increase of approximately 0.03 points on the standardised PUMA. Sparx-recommended usage of Sparx Maths (39 hours, as outlined above) is associated with an increase of approximately 1.3 points on the PUMA score (or 10 per cent of a standard deviation), equivalent to an increase of approximately 0.18 of a forecasted GCSE grade. In other words, 217 hours of Sparx Maths usage (i.e. passive time spent watching educational videos and time spent working on set tasks) would be associated with an increase of 1 GCSE grade (for instance from 5 to 6, or 6 to 7).

Table 6. Relationship between Sparx usage (hours) and maths outcomes

Outcome: PUMA standardised scores	Coef.	Std. Err.	P>z	[95% Conf. Interval]		GCSE
Time spent (in hours) using Sparx Maths	0.033	0.010	0.001	0.014	0.053	0.18 grades

Note: Number of students, N=3,686. Number of classes, N=160.

We posit that the first analysis above (i.e. model comparing access to Sparx with no access to Sparx) found no statistically significant differences because the binary treatment variable obscures the variability in the amount of Sparx Maths usage in the group with access to Sparx. The assumption broadly underpinning the use of Sparx Maths is that the manner in which participating students use Sparx Maths, in terms of frequency of use, duration of sessions and methods of learning using the platform, are key factors associated with impact on outcomes. This is in line with the Sparx Theory of Change (see Appendix A), where learning gains are achieved through sustained and regular engagement with the programme (i.e. through personalised learning and instant feedback). This interpretation is further supported by the finding from the second analysis (i.e. Sparx usage as measured by hours) where time spent using Sparx Maths is positively and statistically significantly associated with maths outcomes. This is also in line with much of the previous evidence on digital learning, where the mere presence of a technology-enabled intervention is not necessarily sufficient to achieve desired impacts.[15]

Additional analysis

Additional to the study plan, one set of analyses was carried out to explore the relationship between the type of different aspects of Sparx Maths usage. Despite two different Sparx Maths products being available, the boundaries between usage of the two products are not clear in regular school practice, with the homework-only product occasionally being used in classroom settings, suggesting that any association between usage (or time) of Sparx Maths homework may be supplemental to the effect from Sparx Maths classroom instead of separate. This would not allow for valid inference about the independent relationship between each of these two products and maths outcomes respectively. This is further complicated by the self-selection of schools into this usage condition, rendering the results of this analysis uninterpretable.

Regardless of the specific product, however, time spent using Sparx Maths is routinely split between time spent *working* (e.g. completing set tasks as opposed to watching educational videos) and time on other activities (e.g. watching tutorials). The overall measure was used in the primary analysis above, but in an additional model we are able to estimate the relationship between working time in Sparx Maths and maths

[15] Education Endowment Foundation. 2019. 'Digital Technology'. Teaching & Learning Toolkit. As of 14 December 2020: https://educationendowmentfoundation.org.uk/pdf/generate/?u=https://educationendowmentfoundation.org.uk/pdf/toolkit/?id=134&t=Teaching and Learning Toolkit&e=134&s=

outcomes. Full specifications of the model can be found in Appendix B3 – Additional analysis. This model uses the same specification as above, controlling for students' prior attainment at KS2, gender, FSM eligibility, EAL status, and month of birth, and accounting for the classroom clustering, but the time variable is restricted to working time only.

The results (Table 7) suggest a positive and statistically significant association between Sparx Maths *working* time and outcomes in maths. Each additional *working* hour in Sparx Maths was associated with an increase of approximately 0.05 marks (or around 0.0035 of a standard deviation) in maths scores. The 39-hour recommended Sparx Maths usage was associated with an increase of approximately 1.95 points (approximately 0.14 of a standard deviation) on the PUMA. This is equivalent to 0.275 of a GCSE grade; in other words, 141 working hours of Sparx (i.e. time spent working on set tasks) would be associated with one whole grade increase in GCSE scores.

Table 7. Relationship between Sparx Maths time spent working (hours) and standardised PUMA scores

Outcome: PUMA standardised scores	Coef.	Std. Err.	P>z	[95% Conf. Interval]		GCSE
Time spent working using Sparx Maths	0.050	0.011	0.000	0.028	0.071	0.275 grades

Note: Number of students, N=3,686. Number of classes, N=160.

These findings further emphasise that it is the nature of Sparx Maths usage that is essential. Specifically, and in line with the Theory of Change, active engagement with Sparx Maths is more strongly associated with maths outcomes than overall time spent on the platform.

Subgroup analyses

This section presents results of multi-level models estimated to isolate the relationship between Sparx Maths usage (as access to, and separately as overall time) on the maths outcomes of the following student subgroups: students with EAL, students eligible for FSM and students with lower prior attainment as measured by those scoring in the bottom quartile of the KS2 score distribution.

The access-focused models each represent a respecified version of the model used in the primary outcome analysis: the same indicator for access to Sparx Maths (the binary variable) is used; and the same background characteristics are controlled for, respectively removing the background variable that is being interacted with access to Sparx (i.e. the variable defining the subgroup) from the list of controls, given that all levels of the subgroup characteristic are already accounted for in the interaction.

The time-focused models employ a similar respecification of the relevant primary analysis model, with the analysis undertaken for each respective subgroup as an interaction with the continuous variable for time spent using Sparx Maths. Full model specifications can be for the subgroup analyses can be found in Appendix B4 – Subgroup analyses.

The above binary interaction models above allow for two research questions to be explored for each of the sub-groups, without additional estimation: first, if within each sub-group, access to Sparx Maths is associated with higher maths outcomes compared with no access; and second, if within the group with access to Sparx Maths, sub-group members performed differently from non-sub-group members.

English as an additional language (EAL)

For students with English as an additional language, the interaction model points to no evidence of a statistically significant difference in maths outcomes by access to Sparx Maths (Table 8); nor any evidence of a relationship between time in Sparx Maths (in hours) and maths outcomes.

When looking within the group with access to Sparx Maths, compared with non-EAL students, EAL students with access to Sparx Maths had statistically significantly better maths outcomes. This reflects the additive effect of EAL sub-group membership *and* having access to Sparx. It suggests that any attainment gaps between EAL and non-EAL students initially present in the group with access to Sparx Maths persist. As stated above, the data structure does not allow for a causal relation to be estimated, nor for effects of the approach to selection into Sparx Maths in each school to be fully understood. Therefore, and given the scope and average usage of the intervention, as seen above in the primary outcome analysis, this is not surprising.

Table 8. Relationship between Sparx Maths and maths outcomes for EAL students

EAL students Outcome: PUMA standardised scores	Coef.	Std. Err.	P>z	[95% Conf. Interval]	
Access to Sparx Maths for EAL students (compared with no access to Sparx Maths)	0.213	1.735	0.902	-3.187	3.614
EAL students in Sparx Maths (compared with non-EAL students in Sparx Maths)	1.537	0.710	0.030	0.145	2.930
Time spent (in hours) using Sparx Maths	-0.005	0.015	0.756	-0.033	0.024

Note: The first model (line 1 and 2) estimates the effect of access to Sparx Maths for the EAL subgroup; and the differential effect of having access to Sparx Maths for EAL students compared to non-EAL students respectively (Table 19). The second model (line 3) estimates the effect of time spent using Sparx Maths within the EAL subgroup (Table 20). Models: Number of students, N=3,686; Number of classes, N=160.

Free school meal eligibility

For students eligible for Free School Meals, the results (Table 9) follow a slightly different pattern from that of the EAL sub-group. The model exploring access to Sparx Maths reveals no evidence of a relationship to maths outcomes for FSM-eligible students, neither of a relationship between hours of Sparx Maths usage and maths outcomes. Additionally, there is no evidence of FSM and non-FSM students with access to Sparx Maths performing differently from each other, with the difference in maths outcomes between these sub-groups with access to Sparx being statistically non-significant.

Table 9. Relationship between Sparx Maths and maths outcomes for students eligible for FSM

Students eligible for FSM Outcome: PUMA standardised scores	Coef.	Std. Err.	P>z	[95% Conf. Interval]	
Access to Sparx Maths for FSM students (compared with no access to Sparx Maths)	-0.723	1.138	0.525	-2.953	1.507
FSM students in Sparx Maths (compared with non-FSM students in Sparx Maths)	-0.663	0.486	0.173	-1.616	0.290
Time spent (in hours) using Sparx Maths	-0.012	0.014	0.359	-0.039	0.014

Note: The first model (line 1 and 2) estimates the effect of access to Sparx Maths within the FSM subgroup; and the differential effect of having access to Sparx Maths for FSM-eligible students compared with non-FSM students respectively (Table 21). The second model (line 3) estimates the effect of time spent using Sparx Maths within the FSM subgroup (Table 22). In all models: Number of students, N=3,686; Number of classes, N=160.

Lower quartile Key Stage 2 scores

Finally, results for the students in the bottom quartile of the KS2 distribution point to a similar pattern of no evidence of an association between access to Sparx Maths, or respectively hours using Sparx Maths, and maths outcomes for this sub-group (Table 10).

Finally, within the group of students with access to Sparx Maths, students with low KS2 attainment show lower levels of maths outcomes compared with students with high KS2 attainment. This reflects initial attainment differentials as defined by KS2 performance and suggests that these attainment gaps are persistent and difficult to shift even among the group that has access to Sparx Maths.

Table 10. Relationship between Sparx Maths and maths outcomes for students with low KS2 attainment

Bottom KS2 group Outcome: PUMA standardised scores	Coef.	Std. Err.	P>z	[95% Conf. Interval]	
Access to Sparx Maths for low KS2 students (compared with no access to Sparx Maths)	-0.665	1.708	0.697	-4.013	2.682
Low KS2 students in Sparx Maths (compared with high-KS2 students in Sparx Maths)	-6.859	0.612	0.000	-9.459	-2.928
Time spent (in hours) using Sparx Maths	-0.003	0.015	0.826	-0.032	0.025

Note: The first model (line 1 and 2) estimates the effect of access to Sparx Maths among students with lower prior attainment at KS2, and the differential effect of having access to Sparx Maths for students with low KS2 attainment compared with students with high KS2 attainment respectively (Table 23). The second model (line 3) estimates the effect of time spent using Sparx Maths among students with lower prior attainment at KS2 (Table 24). In both models: Number of students, N=3,686; Number of classes, N=160.

Exploratory analyses – Propensity score matching

As per the study plan, the research team explored the possibility of establishing a stronger (though not perfect) counterfactual by using propensity score matching (PSM). The first step was to identify covariates that had a statistically significant association with Sparx Maths access, using the same binary indicator used in the primary outcome analysis. The comparison group consisted of students who did not have access to Sparx Maths. As in the primary analysis, 2,406 students were categorised as having access to Sparx Maths, and 1,550 students were part of the comparison group; however, the distribution by year group was not uniform, as none of the Year 7 students in the data part of the comparison group. In other words, instead of including a mix of pupils from Year 7 and Year 8 in the comparison group, only Year 8 students were retained in this analysis, a departure from the planned analysis in the study plan. This resulted in a total sample of 2,369 students for the PSM analysis, of which 819 were in receipt of Sparx Maths, and 1,550 were in the comparison group.

A step-wise process was used to carry out the PSM. First, a propensity score was estimated based on a logistic regression model that included student-level characteristics only. Once the propensity score was estimated, the balance was checked between the 'treated' (i.e. those with access to Sparx Maths) and comparison group (i.e. those without access to Sparx Maths), on each control variable, both on the unmatched, and then the matched sample. Table 11 illustrates these results, showing an overall better balance for the matched sample, and an overall reduction in the bias that would be associated with the analysis without matching.

Table 11. Balance on student-level covariates: matched and unmatched samples

Variable		Matched / Unmatched	Mean (Treated)	Mean (Control)	% bias	% bias reduction	t	p>t
Gender	Male	U	0.453	0.482	-5.8		-1.780	0.075
		M	0.352	0.340	2.4	59.4	0.480	0.629
	Missing	U	0.109	0.045	24.4		7.180	0.000
		M	0.314	0.321	-2.5	89.9	-0.270	0.784
FSM	FSM students	U	0.337	0.461	-25.5		-7.880	0.000
		M	0.119	0.112	1.3	94.7	0.400	0.690
	Missing	U	0.002	0.010	-11.2		-3.750	0.000
		M	0.001	0.004	-3.4	69.9	-1.000	0.317
EAL	EAL students	U	0.067	0.033	15.7		4.650	0.000
		M	0.060	0.068	-3.6	77	-0.630	0.531
	Missing	U	0.002	0.010	-11.2		-3.750	0.000
		M	0.001	0.004	-3.4	69.9	-1.000	0.317
KS2 Standardised Scores		U	103.18	102.96	3.4		0.78	0.438
		M	103.33	104.28	-14.5	-329.2	-3.01	0.003
		U	0.079	0.076	0.9		0.280	0.781

MOB	Feb	M	0.070	0.065	2	-115.1	0.410	0.685
	Mar	U	0.077	0.091	-4.9		-1.520	0.128
		M	0.087	0.117	-10.8	-119.5	-1.940	0.053
	Apr	U	0.091	0.079	4.2		1.270	0.203
		M	0.090	0.106	-5.6	-34.1	-1.030	0.303
	May	U	0.095	0.085	3.6		1.100	0.274
		M	0.085	0.066	6.4	-78.1	1.350	0.177
	Jun	U	0.091	0.074	6.1		1.860	0.063
		M	0.091	0.119	-9.9	-62.7	-1.750	0.080
	Jul	U	0.087	0.085	0.8		0.230	0.817
		M	0.080	0.069	3.7	-391.9	0.780	0.436
	Aug	U	0.088	0.092	-1.2		-0.380	0.707
		M	0.095	0.077	6.4	-421.5	1.270	0.203
	Sep	U	0.086	0.083	1		0.310	0.757
		M	0.089	0.103	-5.2	-410.5	-0.950	0.340
	Oct	U	0.081	0.093	-4.2		-1.300	0.194
		M	0.073	0.064	3.2	23	0.710	0.479
	Nov	U	0.084	0.085	-0.6		-0.180	0.858
		M	0.083	0.073	3.8	-543.8	0.760	0.447
	Dec	U	0.064	0.079	-5.9		-1.830	0.068
		M	0.070	0.074	-1.5	74.1	-0.300	0.768
	Missing	U	0.010	0.002	10.1		2.900	0.004
		M	0.010	0.004	8.6	14.5	1.510	0.130

We note that in the matched sample the KS2 attainment balance has shifted, so that KS2 attainment is substantially higher in the control group in the matched sample. This occurs as a result of all the other student characteristics being included in the matching and, on a broader level, illustrates the difficulties of implementing a post-hoc PSM approach.

Before reporting the average treatment effect on the treated (ATT), Table 12 presents average PUMA scores for the unmatched sample. These initial results indicate that there was no statistically significant difference (p=0.069) in maths outcomes between students using Sparx Maths and the matched comparison group of Year 8 students.

Table 12. Propensity score matching results

Outcome measure	Sample	Treated	Controls	Difference	S.E.	T	P
PUMA standardised scores	Unmatched	104.289	102.349	1.938	0.630	3.08	0.002
	ATT	104.289	106.509	-2.220	1.217	-1.82	0.069
N on common support		1,434	767				

The above analysis, however, does not account for the clustering of students in classes (as would match the primary outcome analysis above). To do so, as a robustness check, a similar model as the primary outcome is estimated, using the PSM score as a weight, but otherwise retaining the same specification. The results of this (Table 13, full model specifications can be found in Appendix B5 – Propensity score matching) point to a similar conclusion: statistically non-significant association between Sparx Maths and maths outcomes, even though the sign of the coefficient is now positive, which suggests that the class-level selection into Sparx Maths may provide some insight into the driving force behind these results. Regrettably, the structure of the data does not allow for either a random effects (multi-level) estimation of the propensity score in the first place, which would be a more robust approach, or a balanced sample with respect to schools or classes

Table 13. Propensity score matching results from multi-level model

Outcome: PUMA standardised scores	Coef.	Std. Err.	P>z	[95% Conf. Interval]	
Access to Sparx Maths	0.470	1.679	0.780	-2.821	3.761

Overall, then, the results of the propensity score matching show that there is no evidence that maths scores differed for Year 8 students depending on their access to Sparx Maths. This matches the results of the first primary outcome analysis (i.e. access to Sparx Maths compared with no access to Sparx Maths) that did not find any statistically significant difference on outcomes between those with access to Sparx Maths compared with those without access to Sparx. However, as later observed, research suggests that access to digital learning tools alone is not enough to improve educational outcomes. This is further supported by Sparx Maths Theory of Change (see Appendix A) and the finding from the second primary analysis that time spent in Sparx Maths, and particularly active working time in Sparx Maths, is associated with better maths outcomes for students. This suggests that further research in this area should be careful not to confound access to digital learning with usage, and instead focus on collecting and analysing active usage (e.g. time spent using programme).

Conclusion

Overall, the primary outcome analysis indicates that while access to Sparx Maths does not produce statistically significant differences in maths outcomes, *time spent using* Sparx Maths is positively associated with maths outcomes. The analysis indicated that more time spent using Sparx Maths was associated with better maths outcomes. Using Sparx Maths for the recommended one hour per week for one whole school year is associated with an increase of almost 20 per cent of a (predicted) GCSE grade.

Based on the findings from the additional analysis, it appears that active use of Sparx Maths is a particularly important mechanism for driving improvement in maths outcomes with a positive and statistically significant association being found between time spent *working* on Sparx Maths and outcomes in maths. Results suggest that the recommended dosage of Sparx Maths (i.e. equal to one hour per week over the academic year) was associated with an increase of approximately 1.95 points (approximately 0.14 of a standard deviation) on the PUMA. This is equivalent to 0.275 of a (predicted) GCSE grade; in other words, 141 working hours of active use of Sparx over a whole school year would be associated with one whole grade increase in GCSE scores. This would be equal to 3.6 hours a week of Sparx Maths usage.

These findings further emphasise that it is the way in which Sparx Maths is used that is essential. Specifically, and in line with the Theory of Change, active engagement with Sparx Maths is more strongly associated with maths outcomes than overall time spent on the platform. This is also in line with previous evidence reviews around the effectiveness of technology-enabled interventions.

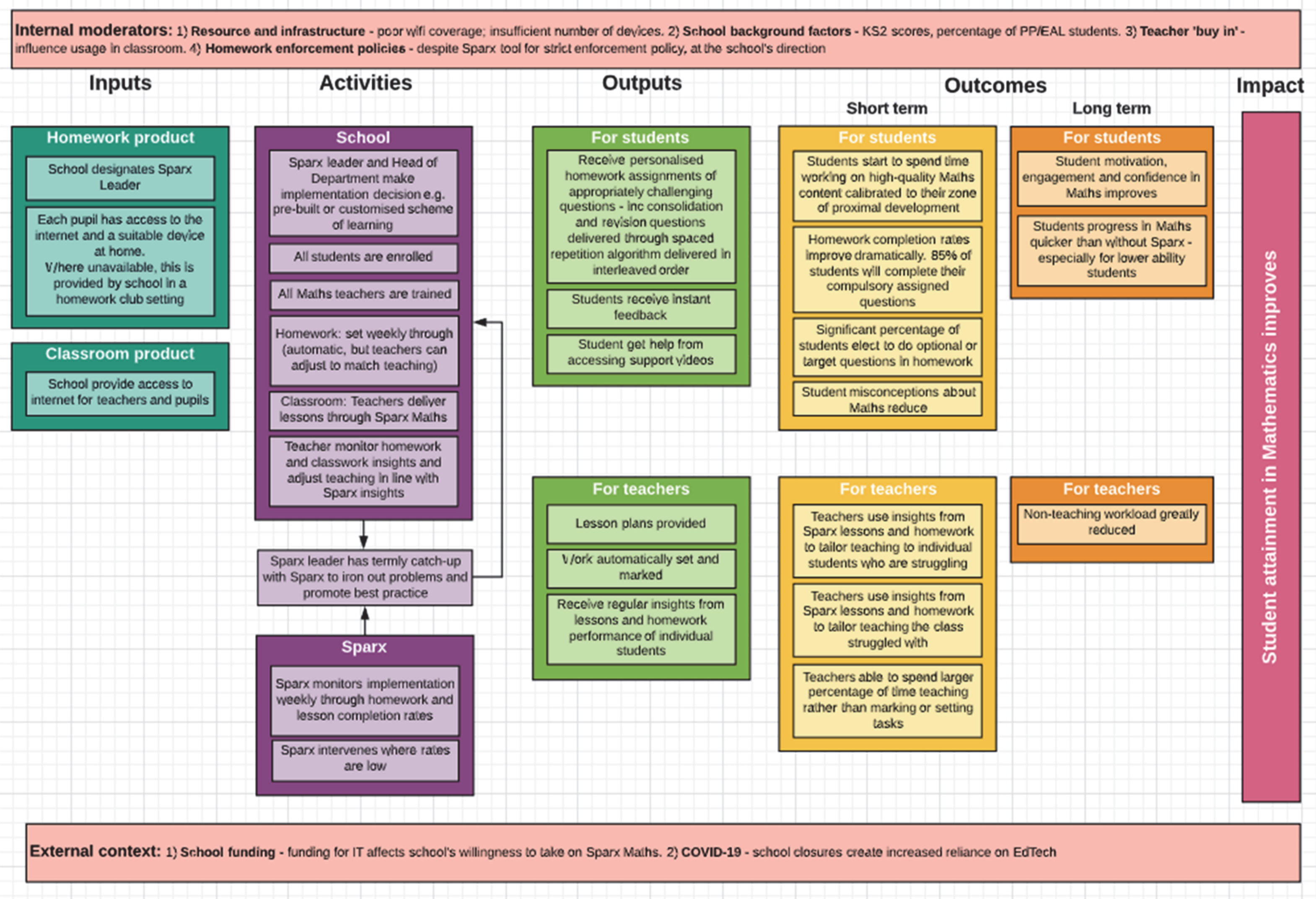
Findings from the subgroup analyses reflect the primary outcome results: within each respective subgroup (EAL, FSM, low-KS2) there is no evidence of different maths scores by access to Sparx Maths. When looking within the group with access to Sparx Maths, initial attainment gaps (on the KS2 measure) appear to be persistent, with little evidence that Sparx Maths is able, on its own, to close these gaps. These findings are not surprising given they mirror what was found in the primary analysis, emphasising that access to digital learning tools is not synonymous with use of the tools or impact on desired outcomes. This finding also aligns with broader evidence around a variety of other education interventions, where even substantially more intensive, higher-cost interventions do not, in isolation, fully address these persistent attainment gaps.

Finally, with the aim of constructing a counterfactual, a propensity score matching (PSM) analysis was undertaken. This approach matched students in Year 8 (where data identified students without access to Sparx Maths) on their individual characteristics; the data did not allow, however, for a balanced sample at the school level, which limits the robustness of the analysis. Additionally, one of the biggest criticisms of quasi-experimental designs (such as PSM) is that they are not able to match on unobservable characteristics and are open to selection bias (in this case selection of classes that receive Sparx Maths). These issues notwithstanding, the results of the PSM analysis are aligned to those of the primary analysis, with no evidence of a statistically significant difference between students with access to Sparx Maths compared with a matched sample of students without access to Sparx Maths in terms of their maths outcomes.

Limitations of this study include an inability to account for selection bias in schools' choice of Sparx Math (i.e. *homework only* or *classroom plus homework*) and a lack of implementation data, for example understanding what drives the differences between students' use of Sparx Maths (i.e. why do some students have access but not use Sparx Maths, why do some students use Sparx more than others). It would also be worth understanding how teachers and schools select students to use Sparx Maths. However, despite these limitations, the results of this study are in line with much of the previous evidence on digital learning, where the mere presence of a technology-enabled intervention is not necessarily sufficient to achieve desired impacts.

Taken together, this suggests that further work is needed to understand the impact of Sparx Maths on outcomes, particularly with the use of a more robust counterfactual and a better understanding of how the platform is implemented in practice. More broadly it also adds to evidence that researchers studying digital learning should avoid confounding access to digital learning with usage, and instead focus on collecting and analysing active usage (e.g. time spent using programme) as part of their research.

Appendix A – Sparx Maths Theory of Change



Appendix B – Full model specifications

Appendix B1 – Missing data analysis

Table 14. Logistic regression model showing missingness in the PUMA standardised score

Outcome: PUMA standardised score	Odds Ratio	Std. Err.	z	P>z	[95% Conf. Interval]	
Gender						
Male	1.223	0.163	1.520	0.130	0.943	1.588
Missing data	1.221	0.329	0.740	0.459	0.720	2.071
FSM eligibility						
FSM students	1.980	0.261	5.170	0.000	1.528	2.564
Missing data	1.398	1.062	0.440	0.659	0.315	6.198
EAL status						
EAL students	0.824	0.264	-0.600	0.547	0.440	1.546
Missing data	1.000	(omitted)				
Month of birth						
January	0.648	0.202	-1.390	0.165	0.351	1.195
February	0.509	0.165	-2.080	0.038	0.270	0.962
March	0.664	0.197	-1.380	0.168	0.371	1.189
April	0.925	0.250	-0.290	0.774	0.545	1.571
May	0.712	0.204	-1.190	0.236	0.407	1.248
June	0.676	0.198	-1.340	0.181	0.380	1.200
July	0.638	0.187	-1.530	0.125	0.359	1.133
September	0.831	0.230	-0.670	0.503	0.482	1.430
October	0.811	0.225	-0.750	0.451	0.471	1.397
November	0.625	0.186	-1.580	0.113	0.349	1.119
December	0.496	0.169	-2.060	0.040	0.254	0.967
Missing data	3.560	1.866	2.420	0.015	1.275	9.944
Constant	0.066	0.014	-12.700	0.000	0.043	0.100

Note: Number of students, N=3,956. Reference categories: Gender (females); FSM eligibility (non-FSM students); EAL status (non-EAL students); Month of birth (August).

Appendix B2 – Primary outcome analysis

Table 15. Relationship between access to Sparx Maths and PUMA standardised scores

Outcome: PUMA standardised score	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
Access to Sparx Maths	-0.508	1.032	-0.490	0.622	-2.531	1.515
KS2 standardised score	1.043	0.033	31.300	0.000	0.978	1.109
Gender						
Male	-0.016	0.287	-0.050	0.956	-0.578	0.547
Missing data	4.052	1.890	2.140	0.032	0.348	7.755
FSM eligibility						
FSM students	-0.522	0.384	-1.360	0.174	-1.275	0.231
Missing data	-8.661	2.826	-3.060	0.002	-14.199	-3.122
EAL status						
EAL students	1.368	0.621	2.200	0.028	0.152	2.585
Missing data	0.000	(omitted)				
Month of birth						
January	0.168	0.688	0.240	0.807	-1.181	1.517
February	0.154	0.671	0.230	0.818	-1.161	1.469
March	-0.468	0.662	-0.710	0.480	-1.766	0.830
April	-0.151	0.657	-0.230	0.818	-1.439	1.136
May	0.433	0.650	0.670	0.505	-0.840	1.706
June	-0.561	0.659	-0.850	0.394	-1.852	0.730
July	-0.203	0.653	-0.310	0.756	-1.483	1.078
September	-0.163	0.664	-0.250	0.806	-1.464	1.137
October	0.415	0.660	0.630	0.529	-0.878	1.709
November	-0.119	0.661	-0.180	0.858	-1.414	1.177
December	0.323	0.692	0.470	0.640	-1.033	1.680
Missing data	-0.233	2.045	-0.110	0.909	-4.241	3.774
Constant	-5.872	3.504	-1.680	0.094	-12.739	0.995

Note: Number of students, N=3,686. Number of classes, N=160. Reference categories: Gender (females); FSM eligibility (non-FSM students); EAL status (non-EAL students); Month of birth (August).

Table 16. Relationship between Sparx Maths usage and PUMA standardised scores

Outcome: PUMA standardised score	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
Time spent (in hours) using Sparx Maths	0.033	0.010	3.370	0.001	0.014	0.053
KS2 standardised score	1.041	0.033	31.310	0.000	0.976	1.107
Gender						
Male	0.057	0.287	0.200	0.842	-0.506	0.621
Missing data	4.770	1.869	2.550	0.011	1.106	8.434
FSM eligibility						
FSM students	-0.380	0.385	-0.990	0.324	-1.135	0.375
Missing data	-9.302	2.804	-3.320	0.001	-14.798	-3.805
EAL status						
EAL students	1.331	0.620	2.150	0.032	0.116	2.546
Missing data	0.000	(omitted)				
Month of birth						
January	0.193	0.687	0.280	0.779	-1.155	1.540
February	0.170	0.670	0.250	0.800	-1.144	1.483
March	-0.466	0.661	-0.700	0.481	-1.762	0.831
April	-0.131	0.656	-0.200	0.842	-1.417	1.155
May	0.424	0.649	0.650	0.513	-0.848	1.696
June	-0.590	0.658	-0.900	0.370	-1.879	0.700
July	-0.219	0.653	-0.340	0.737	-1.498	1.060
September	-0.153	0.663	-0.230	0.818	-1.452	1.146
October	0.421	0.659	0.640	0.523	-0.871	1.713
November	-0.099	0.660	-0.150	0.881	-1.393	1.196
December	0.358	0.691	0.520	0.605	-0.997	1.713
Missing data	0.945	2.073	0.460	0.648	-3.118	5.008
Constant	-6.971	3.445	-2.020	0.043	-13.722	-0.219

Note: Number of students, N=3,686. Number of classes, N=160. Reference categories: Gender (females); FSM eligibility (non-FSM students); EAL status (non-EAL students); Month of birth (August).

Table 17. Relationship between Sparx Maths usage and forecasted GCSE grades

Outcome: Forecasted GCSE grade	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
Time spent (in hours) using Sparx Maths	0.005	0.001	3.290	0.001	0.002	0.007
KS2 standardised score	0.147	0.005	31.540	0.000	0.138	0.156
Gender						
Male	0.010	0.040	0.240	0.810	-0.069	0.089
Missing data	0.660	0.261	2.530	0.011	0.148	1.171
FSM eligibility						
FSM students	-0.055	0.054	-1.010	0.311	-0.161	0.051
Missing data	-1.292	0.393	-3.290	0.001	-2.062	-0.523
EAL status						
EAL students	0.187	0.087	2.150	0.032	0.016	0.357
Missing data	0.000	(omitted)				
Month of birth						
January	0.027	0.096	0.270	0.784	-0.163	0.216
February	0.022	0.094	0.240	0.814	-0.162	0.206
March	-0.066	0.093	-0.710	0.478	-0.248	0.116
April	-0.013	0.092	-0.140	0.891	-0.193	0.168
May	0.061	0.091	0.670	0.505	-0.118	0.239
June	-0.086	0.092	-0.930	0.350	-0.267	0.095
July	-0.030	0.092	-0.330	0.741	-0.210	0.149
September	-0.015	0.093	-0.160	0.870	-0.198	0.167
October	0.057	0.093	0.610	0.540	-0.125	0.238
November	0.001	0.093	0.010	0.993	-0.181	0.183
December	0.052	0.097	0.530	0.596	-0.139	0.242
Missing data	0.118	0.291	0.410	0.684	-0.452	0.688
Constant	-10.477	0.483	-21.680	0.000	-11.424	-9.530

Note: Number of students, N=3,679. Number of classes, N=160. Reference categories: Gender (females); FSM eligibility (non-FSM students); EAL status (non-EAL students); Month of birth (August).

Appendix B3 – Additional analysis

Table 18. Relationship between time spent (hours) working in Sparx Maths and PUMA standardised scores

Outcome: PUMA standardised score	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
Time spent working using Sparx Maths	0.050	0.011	4.570	0.000	0.028	0.071
KS2 standardised score	1.036	0.033	31.160	0.000	0.971	1.102
Gender						
Male	0.066	0.287	0.230	0.818	-0.496	0.628
Missing data	5.060	1.878	2.690	0.007	1.378	8.741
FSM eligibility						
FSM students	-0.336	0.385	-0.870	0.382	-1.090	0.418
Missing data	-9.589	2.808	-3.410	0.001	-15.093	-4.085
EAL status						
EAL students	1.323	0.619	2.140	0.033	0.110	2.537
Missing data	0.000	(omitted)				
Month of birth						
January	0.210	0.686	0.310	0.760	-1.136	1.555
February	0.196	0.669	0.290	0.770	-1.116	1.508
March	-0.455	0.660	-0.690	0.491	-1.750	0.839
April	-0.115	0.655	-0.180	0.861	-1.399	1.169
May	0.432	0.648	0.670	0.505	-0.838	1.702
June	-0.590	0.657	-0.900	0.369	-1.878	0.697
July	-0.216	0.652	-0.330	0.741	-1.493	1.062
September	-0.129	0.662	-0.200	0.845	-1.427	1.168
October	0.429	0.658	0.650	0.515	-0.861	1.719
November	-0.085	0.659	-0.130	0.897	-1.378	1.207
December	0.376	0.690	0.550	0.586	-0.977	1.729
Missing data	1.371	2.070	0.660	0.508	-2.686	5.428
Constant	-6.799	3.441	-1.980	0.048	-13.543	-0.054

Note: Number of students, N=3,686. Number of classes, N=160. Reference categories: Gender (females); FSM eligibility (non-FSM students); EAL status (non-EAL students); Month of birth (August).

Appendix B4 – Subgroup analyses

Table 19. Relationship between access to Sparx Maths and maths outcomes for EAL students

Outcome: PUMA standardised score	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
EAL interactions						
Non-EAL / no Sparx Maths access	-0.795	1.272	-0.630	0.532	-3.288	1.698
Non-EAL / access to Sparx Maths	-1.324	1.605	-0.820	0.409	-4.470	1.822
EAL / access to Sparx Maths	0.213	1.735	0.120	0.902	-3.187	3.614
MD: EAL / no Sparx Maths access	-8.746	3.136	-2.790	0.005	-14.892	-2.600
MD: EAL / access to Sparx Maths	-16.985	6.708	-2.530	0.011	-30.132	-3.839
KS2 standardised score	1.042	0.033	31.280	0.000	0.977	1.108
Gender						
Male	-0.011	0.287	-0.040	0.969	-0.574	0.551
Missing data	4.073	1.891	2.150	0.031	0.366	7.780
FSM eligibility						
FSM students	-0.523	0.384	-1.360	0.173	-1.276	0.230
Missing data	0.000	(omitted)				
Month of birth						
January	0.183	0.688	0.270	0.790	-1.166	1.532
February	0.159	0.671	0.240	0.813	-1.156	1.474
March	-0.468	0.662	-0.710	0.480	-1.766	0.830
April	-0.133	0.657	-0.200	0.839	-1.421	1.155
May	0.434	0.650	0.670	0.504	-0.839	1.708
June	-0.557	0.658	-0.850	0.397	-1.848	0.733
July	-0.202	0.653	-0.310	0.757	-1.483	1.078
September	-0.163	0.663	-0.250	0.806	-1.463	1.137
October	0.413	0.660	0.630	0.531	-0.880	1.706
November	-0.114	0.661	-0.170	0.863	-1.410	1.181
December	0.332	0.692	0.480	0.632	-1.024	1.688
Missing data	0.387	2.113	0.180	0.855	-3.755	4.529
Constant	-4.991	3.707	-1.350	0.178	-12.257	2.275

Note: Number of students, N=3,686. Number of classes, N=160. Reference categories: EAL interaction (EAL / no Sparx Maths access); Gender (females); FSM (non-FSM students); EAL (non-EAL students); Month of birth (August).

Table 20. Relationship between time in Sparx Maths (hours) and maths outcomes for EAL students

Outcome: PUMA standardised score	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
EAL/time spent (hours) in Sparx interaction						
EAL students	-0.005	0.015	-0.310	0.756	-0.033	0.024
Missing data	-10.091	6.872	-1.470	0.142	-23.561	3.378
Time spent (hours) in Sparx	0.034	0.010	3.370	0.001	0.014	0.054
EAL status						
EAL students	1.493	0.820	1.820	0.069	-0.115	3.101
Missing data	-8.711	2.833	-3.070	0.002	-14.264	-3.158
KS2 standardised scores	1.041	0.033	31.320	0.000	0.976	1.107
Gender						
Males	0.056	0.287	0.200	0.845	-0.507	0.619
Missing data	4.778	1.869	2.560	0.011	1.114	8.442
FSM status						
FSM students	-0.387	0.385	-1.000	0.315	-1.142	0.368
Missing data	0.000	(omitted))				
Month of birth						
January	0.197	0.687	0.290	0.774	-1.150	1.544
February	0.167	0.670	0.250	0.804	-1.147	1.480
March	-0.454	0.661	-0.690	0.493	-1.750	0.843
April	-0.130	0.656	-0.200	0.843	-1.416	1.156
May	0.433	0.649	0.670	0.505	-0.839	1.705
June	-0.589	0.658	-0.890	0.371	-1.878	0.701
July	-0.216	0.653	-0.330	0.741	-1.495	1.063
September	-0.149	0.663	-0.220	0.822	-1.448	1.150
October	0.429	0.659	0.650	0.516	-0.863	1.721
November	-0.087	0.661	-0.130	0.896	-1.381	1.208
December	0.368	0.691	0.530	0.595	-0.987	1.722
Missing data	1.515	2.107	0.720	0.472	-2.615	5.646
Constant	-6.986	3.445	-2.030	0.043	-13.738	-0.235

Note: Number of students, N=3,686. Number of classes, N=160. Reference categories: Interaction term (non-EAL students); EAL status (non-EAL students); Gender (females); FSM status (non-FSM); Month of birth (August).

Table 21. Relationship between access to Sparx Maths and maths outcomes for students receiving FSM

Outcome: PUMA standardised score	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
FSM interactions						
Non-FSM / no Sparx Maths access	0.289	0.623	0.460	0.643	-0.933	1.510
Non-FSM / access to Sparx Maths	-0.060	1.102	-0.050	0.956	-2.220	2.100
FSM / access to Sparx Maths	-0.723	1.138	-0.640	0.525	-2.953	1.507
MD: FSM / no Sparx Maths access	-7.479	2.903	-2.580	0.010	-13.168	-1.789
MD: FSM / access to Sparx Maths	-15.792	6.608	-2.390	0.017	-28.743	-2.842
KS2 standardised score	1.042	0.033	31.270	0.000	0.977	1.108
Gender						
Male	-0.016	0.287	-0.060	0.956	-0.578	0.546
Missing data	4.039	1.891	2.140	0.033	0.332	7.746
EAL status						
EAL students	1.359	0.621	2.190	0.029	0.142	2.575
Missing data	0.000	(omitted)				
Month of birth						
January	0.184	0.688	0.270	0.789	-1.165	1.533
February	0.157	0.671	0.230	0.815	-1.158	1.471
March	-0.455	0.662	-0.690	0.492	-1.753	0.843
April	-0.142	0.657	-0.220	0.829	-1.429	1.145
May	0.444	0.650	0.680	0.494	-0.829	1.717
June	-0.556	0.658	-0.840	0.399	-1.846	0.735
July	-0.197	0.653	-0.300	0.763	-1.477	1.083
September	-0.154	0.664	-0.230	0.816	-1.455	1.147
October	0.421	0.660	0.640	0.524	-0.872	1.714
November	-0.113	0.661	-0.170	0.864	-1.408	1.183
December	0.330	0.692	0.480	0.633	-1.026	1.686
Missing data	0.421	2.113	0.200	0.842	-3.721	4.562
Constant	-6.188	3.509	-1.760	0.078	-13.066	0.691

Note: Number of students, N=3,686. Number of classes, N=160. Reference categories: FSM interaction (FSM / no Sparx Maths access); Gender (females); FSM (non-FSM students); EAL (non-EAL students); Month of birth (August).

Table 22. Relationship between time in Sparx Maths (hours) and maths outcomes for students receiving FSM

Outcome: PUMA standardised score	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
FSM/time spent (hours) in Sparx interaction						
FSM students	-0.012	0.014	-0.920	0.359	-0.039	0.014
Missing data	-10.204	6.873	-1.480	0.138	-23.675	3.267
Time spent (hours) in Sparx	0.035	0.010	3.480	0.000	0.015	0.054
FSM status						
FSM students	-0.141	0.470	-0.300	0.764	-1.063	0.781
Missing data	-8.588	2.835	-3.030	0.002	-14.144	-3.031
KS2 standardised scores	1.041	0.033	31.300	0.000	0.976	1.106
Gender						
Males	0.050	0.287	0.170	0.863	-0.514	0.613
Missing data	4.809	1.868	2.570	0.010	1.147	8.470
EAL status						
EAL students	1.311	0.620	2.110	0.034	0.096	2.526
Missing data	0.000	(omitted))				
Month of birth						
January	0.212	0.687	0.310	0.757	-1.135	1.560
February	0.186	0.670	0.280	0.782	-1.128	1.499
March	-0.443	0.661	-0.670	0.503	-1.740	0.853
April	-0.118	0.656	-0.180	0.857	-1.404	1.168
May	0.453	0.649	0.700	0.486	-0.820	1.725
June	-0.570	0.658	-0.870	0.386	-1.859	0.720
July	-0.204	0.653	-0.310	0.754	-1.483	1.075
September	-0.133	0.663	-0.200	0.841	-1.432	1.166
October	0.448	0.660	0.680	0.497	-0.845	1.741
November	-0.083	0.660	-0.130	0.900	-1.377	1.211
December	0.379	0.691	0.550	0.583	-0.976	1.734
Missing data	1.425	2.104	0.680	0.498	-2.700	5.549
Constant	-6.975	3.443	-2.030	0.043	-13.723	-0.227

Note: Number of students, N=3,686. Number of classes, N=160. Reference categories: Interaction term (non-FSM students); FSM status (non-FSM students); (Gender (females); EAL status (non-EAL students); Month of birth (August).

Table 23. Relationship between access to Sparx Maths and PUMA standardised scores for students with lower prior attainment at KS2 level

Outcome: PUMA standardised score	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
KS2 interactions						
Higher KS2 / No Sparx access	6.164	0.728	8.470	0.000	4.737	7.590
Higher KS2 / access to Sparx	6.194	1.666	3.720	0.000	2.928	9.459
Bottom quartile KS2 / access to Sparx	-0.665	1.708	-0.390	0.697	-4.013	2.682
Gender						
Male	0.506	0.305	1.660	0.097	-0.092	1.104
Missing data	5.436	2.888	1.880	0.060	-0.224	11.097
FSM status						
FSM students	-0.604	0.415	-1.460	0.145	-1.418	0.209
Missing data	-10.001	3.654	-2.740	0.006	-17.164	-2.839
EAL status						
EAL students	1.265	0.662	1.910	0.056	-0.033	2.562
Missing data	0.000	(omitted)				
Month of birth						
January	0.691	0.733	0.940	0.345	-0.745	2.128
February	0.536	0.715	0.750	0.453	-0.865	1.937
March	-0.342	0.706	-0.480	0.628	-1.726	1.041
April	-0.128	0.700	-0.180	0.855	-1.500	1.244
May	0.603	0.693	0.870	0.384	-0.755	1.961
June	-0.283	0.702	-0.400	0.687	-1.658	1.092
July	-0.066	0.696	-0.090	0.925	-1.430	1.299
September	0.597	0.706	0.840	0.398	-0.788	1.981
October	0.679	0.703	0.970	0.334	-0.698	2.057
November	0.107	0.705	0.150	0.880	-1.274	1.487
December	0.384	0.738	0.520	0.603	-1.063	1.830
Missing data	1.238	2.179	0.570	0.570	-3.033	5.509
Constant	95.699	1.439	66.500	0.000	92.878	98.519

Note: Number of students, N=3,686. Number of classes, N=160. Reference categories: KS2 interaction (Bottom quartile KS2 / no Sparx access); Gender (females); FSM (non-FSM students); EAL (non-EAL students); Month of birth (August).

Table 24. Relationship between time in Sparx Maths and PUMA standardised scores for students with lower prior attainment at KS2 level

Outcome: PUMA standardised score	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
KS2 scores/time spent (hours) in Sparx						
Bottom quartile	-0.003	0.015	-0.220	0.826	-0.032	0.025
Time spent (hours) in Sparx	0.041	0.012	3.390	0.001	0.017	0.065
Bottom quartile for KS2 scores	-6.440	0.558	-11.550	0.000	-7.533	-5.347
Gender						
Male	0.591	0.306	1.930	0.053	-0.008	1.190
Missing data	6.383	2.870	2.220	0.026	0.758	12.008
FSM status						
FSM students	-0.478	0.416	-1.150	0.250	-1.293	0.337
Missing data	-10.995	3.634	-3.030	0.002	-18.117	-3.873
EAL status						
EAL students	1.253	0.661	1.900	0.058	-0.042	2.549
Missing data	0.000	(omitted)				
Month of birth						
January	0.729	0.732	1.000	0.319	-0.706	2.164
February	0.572	0.714	0.800	0.423	-0.827	1.971
March	-0.332	0.705	-0.470	0.638	-1.714	1.050
April	-0.084	0.699	-0.120	0.904	-1.454	1.286
May	0.606	0.692	0.880	0.381	-0.750	1.962
June	-0.294	0.701	-0.420	0.675	-1.668	1.080
July	-0.076	0.695	-0.110	0.913	-1.439	1.286
September	0.625	0.706	0.890	0.376	-0.758	2.008
October	0.694	0.702	0.990	0.323	-0.682	2.069
November	0.146	0.704	0.210	0.836	-1.233	1.525
December	0.439	0.737	0.600	0.551	-1.005	1.883
Missing data	2.747	2.223	1.240	0.216	-1.609	7.103
Constant	100.669	1.019	98.740	0.000	98.671	102.667

Note: Number of students, N=3,686. Number of classes, N=160. Reference categories: Interaction term (students in top 3 quartiles for KS2 attainment); prior attainment (top 3 quartiles for KS2 attainment); Gender (females); FSM status (non-FSM students); EAL (non-EAL students); Month of birth (August).

Appendix B5 – Propensity score matching

Outcome: PUMA standardised score	Coef.	Std. Err.	z	P>z	[95% Conf. Interval]	
Access to Sparx Maths	0.470	1.679	0.280	0.780	-2.821	3.761
KS2 standardised score	0.875	0.054	16.190	0.000	0.769	0.981
Gender						
Male	0.358	0.486	0.740	0.461	-0.595	1.312
Missing data	3.649	2.388	1.530	0.126	-1.030	8.329
FSM eligibility						
FSM students	-0.939	0.683	-1.380	0.169	-2.277	0.399
Missing data	-15.425	5.598	-2.760	0.006	-26.396	-4.454
EAL status						
EAL students	0.251	0.832	0.300	0.763	-1.379	1.881
Missing data	0.000	(omitted)				
Month of birth						
January	1.258	1.002	1.260	0.209	-0.705	3.221
February	-1.306	1.022	-1.280	0.201	-3.309	0.697
March	-1.283	0.921	-1.390	0.164	-3.088	0.522
April	-1.576	0.924	-1.700	0.088	-3.387	0.236
May	0.832	0.974	0.850	0.393	-1.078	2.741
June	-2.948	0.896	-3.290	0.001	-4.704	-1.192
July	-1.776	0.975	-1.820	0.069	-3.686	0.135
September	-1.795	0.936	-1.920	0.055	-3.630	0.040
October	0.563	1.005	0.560	0.575	-1.407	2.533
November	-2.465	0.969	-2.540	0.011	-4.364	-0.566
December	0.115	0.992	0.120	0.907	-1.830	2.061
Missing data	3.297	2.940	1.120	0.262	-2.465	9.059
Constant	12.016	5.581	2.150	0.031	1.078	22.954

Note: Number of students, N=1,534. Number of classes, N=94. Reference categories: Gender (females); FSM (non-FSM students); EAL (non-EAL students); Month of birth (August).