sparx

Why Sparx Maths Works: Evidence-based Design

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Sparx Maths is an online maths learning platform for Key Stages 3 and 4 that has been developed with the help of many years of active research in schools. This research, together with published evidence of what works in education, has informed the key decisions taken to shape both the in-lesson and homework products offered by Sparx. In this report, we explore the evidence from educational research that helps explain why Sparx Maths is highly effective for improving student learning and helping teachers teach. We begin by defining a set of key features of Sparx that present evidence-based solutions to many of the commonly raised issues around teaching and learning maths, and follow this with a more detailed discussion of how these features are implemented to help meet the needs of students, teachers and schools.

Key features

Aiding the primary-to-secondary transition	Reducing attainment shortfalls during the primary-to-secondary transition by ensuring every student receives tasks that fall within their ability range from the outset.
Personalised learning	Providing bespoke homework that is designed to reflect each student's maths ability and speed of working to ensure everyone does one hour of maths homework each week.
Preventing common misconceptions	Ensuring students don't learn wrong factual knowledge or use methods for solving problems that are commonly confused with the right ones.
Reducing maths anxiety	Helping students develop positive attitudes towards maths and a 'can do' mindset.
Boosting student motivation	Making maths learning relevant, engaging and enjoyable for students of all abilities.

Spaced repetition	Allowing learned material to be revisited regularly rather than in one go, to improve retention.
Interleaving	Providing consolidation and revision questions in homework that are mixed rather than grouped by topic, to help students improve their mathematical understanding.
Lowering burden on working memory	Built-in requirements and checks to ensure students write down their workings where appropriate, such that working memory load is reduced.
Diagnosing the zone of proximal development	Setting personalised questions that fall within each student's 'zone of proximal development'.
Reducing teacher workload	Substantially reducing teacher workload by automating marking and feedback, summarising pupil progress and providing optional lesson plans for every maths lesson in KS3 and KS4, covering 100% of the curriculum.
Automated marking	Providing students with instant feedback on whether a submitted answer is correct or incorrect, for every question in a lesson or a homework assignment.
Improving homework completion rates	Setting weekly homework and providing tools to help teachers ensure it is completed. (Our cumulative completion rate for all students since April 2017 is 95.1%).
Helping teachers provide targeted support to students	Providing teachers with regular insights based on lessons, homework and test results about the performance of individual students and whole classes, pinpointing weaknesses so that they can be addressed directly.

For students

For any educational platform to have a positive impact on student learning, it must cater to the varying needs of learners as they progress through their schooling. In particular, moving from primary to secondary school can be a daunting experience for many students. Some of these students may not have attained the level expected in maths at Key Stage 2, resulting in them facing an increased mental burden, compared with their peers, to learn secondary-level maths and the risk of continuing to fall further behind in progress and attainment (Coad & Jones, 1999). To aid the primary-to-secondary transition for these students, Sparx has created content that specifically caters to their needs. The algorithms used by Sparx can automatically gauge the maths level of a student and thus provide content in homework that is accessible to them, covering everyone from those who are non-secondary ready to the most mathematically-able students. Importantly, this ensures that all students undergo the same subjective learning experience by having the opportunity to tackle maths problems and experience success, so that no one is left feeling isolated.

Alongside providing the most appropriate maths content for students of all abilities, Sparx has built-in mechanisms to maximise learning as students work through their classroom and homework assignments. Where possible, questions are presented using real world examples with accompanying images to help students gain better understanding of a problem through visualisation. In the classroom, students are presented with questions that fall into three categories: Core, Extension and Challenge. Questions that fall in the Core category test pupils' basic knowledge of the mathematical facts behind the topic being taught. These questions are unidimensional in that they explore only one theme in the topic at a time, and allow students to master the subject knowledge required before moving on to more complex problems that draw on a wider range of maths skills. In Extension questions, students begin to solve problems that involve using multiple skills from the same topic while Challenge questions require a broad set of mathematical techniques that students have learned up to that point. Research has highlighted the importance of understanding before problem solving (Carpenter & Lehrer, 1999), and this approach is central to both the lesson and homework products offered by Sparx.

In homework assignments, students are given compulsory questions as well as an extra set of optional questions and a small number of questions deemed suitably challenging for their ability. The compulsory set of questions for each student is generated using algorithms that can predict the student's speed at answering a question and the probability of answering it correctly, given the student's prior homework performance. This allows a homework assignment to be generated such that the compulsory component takes approximately one hour to complete and is neither too easy nor too difficult. Students must revisit incorrect questions until they are able to answer them correctly. This reduces the chance of misconceptions being retained. Misconceptions can arise if a student is not aware that he/she is using an incorrect method, and unless immediately addressed, there is a risk of the student continuing to use the wrong method for similar subsequent questions. Each time a student answers a question incorrectly, they are shown a slightly different version of the original question where the numbers involved are replaced but where the specific learning point remains the same, which can further help distinguish between typing errors and those resulting from an incorrect understanding of the problem. Further, because higher ability students tend to be more resilient when attempting

a difficult problem (Pajares & Graham, 1999), Sparx accounts for this by giving these students questions that have a higher chance of being answered incorrectly. Conversely for lower ability students, homework questions have a lower probability of being answered incorrectly, in order to reduce maths anxiety in these students.

This set of homework questions, delivered on a weekly basis, is entirely personalised and unique to each student. It is designed to ensure that, on average, students do one hour of compulsory maths homework every week with the option to do more should they wish. Whether or not homework improves attainment is a contentious issue, with evidence both supporting (Cooper, Robinson, & Patall, 2006; Trautwein, Köller, Schmitz, & Baumert, 2002) and challenging (Dettmers, Trautwein, & Lüdtke, 2009; Eren & Henderson, 2011) the traditional view that the relationship between homework and attainment is universally positive. To explore this question, we conducted a four-arm, double-blind, randomised controlled trial to investigate the effect of algebra homework length on algebra attainment, and found a significantly positive association between homework length and attainment (Nawaz & Welbourne, 2019).

A negative emotional reaction towards maths, termed maths anxiety, can have an adverse impact on student performance. This relationship can become more apparent when students move from primary to secondary school, and tends to be higher in girls than in boys (Hill et al., 2016). Sparx is designed to empower students to be able to do maths with confidence. This is achieved not only by setting bespoke homework at the appropriate level for each student, but by also providing a video guide for each question that students can refer to when unsure how to proceed. These video guides use worked examples to provide detailed explanations of how to tackle problems. Students are especially encouraged when a correct answer is given after multiple incorrect ones, so that they appreciate their achievement rather than feel their confidence diminish. Students have the option to play maths games after each set of questions in homework has been completed, and can level up in these games using points earned by, for example, doing optional or challenging homework. In our recent study on student motivation, involving over 500 pupils using the Sparx homework platform ("Sparx Motivation questionnaire analysis," 2019), we found no difference in maths confidence and maths enjoyment between boys and girls, and significant positive relationships between each motivation-associated trait (maths confidence, maths enjoyment and perceived importance of maths) and both optional homework completion and progress in half-termly tests, which is evidence not only of the importance of keeping students motivated, but also that among students using Sparx homework there is no significant gender gap in maths confidence.

Alongside the design of content and features that keep students engaged with maths, a great deal of care has been taken to incorporate what we know about the learning process into the design of Sparx. For example, students are never presented with the right answer but are instead encouraged to persist with a question until they can answer it correctly. Self-correction improves self-efficacy and maths attainment (Ramdass & Zimmerman, 2008), which may be explained by increased self-evaluation in these students. This further enables students with high maths anxiety to see maths as 'doable' when they themselves submit the right answer rather than being presented with it by a teacher or the computer.

As students work through their homework each week, they are given questions from the current topic being taught in school as well as consolidation and revision questions taken from material taught in recent weeks (consolidation) or from further back (revision). The

consolidation section prioritises material in the order of the most recent (i.e. the previous week's topics) to the oldest. Research has shown the benefit of spaced repetition over repetition that is grouped together (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Kang, 2016a). However, it is difficult to deduce the optimum time until revisiting a topic in terms of maximising the effect on retention, since this will likely be both learner- and topic-dependent. A recent study on spaced repetition using computer models of student memory found that revisiting material after one week of learning (which is closest to the scheme used in Sparx Maths) had a more favourable effect on retention than revisiting material in a random order (Khajah, Lindsey, & Mozer, 2014). The revision section of Sparx Maths Homework constitutes 10% of a homework assignment and ensures that students regularly revisit all topics to help them build the links between older and newer material and use these links to attempt the more challenging questions in homework. Questions in the consolidation and revision sections are not grouped by topic but are deliberately shuffled. This interleaving reflects the organisation of questions in exam papers and necessitates the use of self-regulatory strategies as students must consider the problem and choose the most appropriate method to solve it (Kang, 2016b), rather than base their choice of strategy on the topic to which they know a question belongs. Interleaving has been shown to help students better differentiate between similar maths concepts (Rohrer, 2012), and boost learning (Rohrer, Dedrick, & Stershic, 2015).

To maximise their problem-solving ability, Sparx presents students with only one method for each type of problem, which is consistently used in all the video guides. Although several studies have presented evidence that teaching students multiple methods for solving maths problems is beneficial for learning, this is based largely on primary school pupils (Lynch & Star, 2014), and concern has been expressed by teachers that for older pupils, learning multiple strategies can be confusing and lead to misconceptions (Silver, Ghousseini, Gosen, Charalambous, & Strawhun, 2005).

To reduce the burden on working memory and help students prepare for written exams, there are built-in requirements and checks to ensure students write down their workings where appropriate. This also enables deeper processing and improves retention. For complex numerical problems, written workings have shown to result in accurate answers more often than mental working for all abilities (Hickendorff, van Putten, Verhelst, & Heiser, 2010), and writing answers by hand has been associated with quicker learning gains compared with typing in algebra (Anthony, Yang, & Koedinger, 2008).

By presenting students with the most appropriate content for their ability, such that they are suitably challenged and encouraged to persist with every question without losing motivation or facing cognitive overload, and with video guides to help them in their independent learning, the Sparx online platform helps to maximise maths learning in each student's zone of proximal development (ZPD) (Chaiklin, 2003; Vygotsky, 1978). The ZPD describes the set of tasks for which a student's capability of completing them independently is not sufficiently mature but which, after some guidance, the student has the potential to complete independently. Questions in Sparx lessons are structured such that all students practise core material that tests maths knowledge, while those with higher ability can further attempt more challenging tasks that are in their ZPD. In homework the ZPD is diagnosed automatically and individually for each student by filtering out questions deemed too easy or difficult. This allows students to regularly access learning in their ZPD, thereby ensuring that each question they tackle contributes to their learning.

For teachers

Results from the 2016 Teacher Workload Survey conducted by the Department for Education (DfE) showed teachers are being increasingly overworked, with 93% of the 3,200 respondents stating that they considered workload to be at least a 'fairly serious problem' and over half describing it as a 'very serious problem' (Higton et al., 2017). In the same report, the DfE also published results from the Workload Challenge, in which teachers were invited to share their opinion on everyday tasks they are required to do but which they find unnecessary and unproductive. The three most commonly reported such tasks by a representative sample of the 17,000 respondents were data collection (56% of respondents), marking (53%) and planning and preparation (38%). In a separate study involving 246 teachers in England and Wales, workload and pupil behaviour were identified as the two most common problems facing teacher recruitment and retention efforts (Barmby, 2006). As such, there is an urgent and unmet need to find solutions to reduce teacher workload in order to help teachers perform their jobs most effectively and improve teacher retention.

Clearly, the most important demand on teachers' time is that of teaching students and of identifying the strengths and weakness of their students in order to provide more focussed support. Therefore, a solution to reduce teacher workload must enable teachers to maximise their impact on student learning by either substantially reducing or entirely eliminating the need for time-consuming tasks, such as those listed above, that teachers feel add relatively little value. The Sparx learning platform offers one such solution.

The Sparx learning platform provides automated marking and instant feedback on correct or incorrect submission of an answer, both during lessons and homework. This information is also made available to teachers in real time, without the need for any marking. In class, the user interface for teachers presents them with live information on every student's progress through a task or activity, and students deemed to be struggling (e.g. if they have made multiple unsuccessful attempts to answer a question or have accessed the video guide for help) are flagged to the teacher so that they can be further supported. Where several students are seen to be struggling on a given question, the teacher can pause the ongoing task on the devices of those students and explain on the whiteboard how to solve the question for their collective benefit, while other students who do not need the guidance can continue with their work. In this way, the interaction between teachers and students is of maximum benefit to the students; higher ability students are not disrupted from their work while lower ability students can access help as and when they require it. If a teacher feels that their class would benefit from repeating the entire lesson, this can be implemented with ease.

As well as automatedly marking students' work, Sparx provides teachers with the three questions that caused most struggle, both for individual students as well as the class as a whole, in each homework assignment. Weekly compulsory and optional homework completion rates are also provided to teachers automatically via the online platform. This removes the need for teachers to carry out analysis of students' work, and simply leaves them with the more important step of revisiting those problems and providing targeted support to students. Further, weekly homework assignments are automatedly generated by the online perform based on the teacher-defined scheme of learning; input is only required when a teacher wishes to add or remove topics from homework, change the set and due dates or alter the quantity of homework given to individual students or the whole class.

Sparx provides lesson plans for every maths lesson in an academic year, covering 100% of the curriculum. Teachers remain free, and are in fact encouraged, to use their own lesson plans where they feel it would be of greater benefit to students. The online platform, however, covers only 70-80% of the curriculum; for as the remaining 20-30%, a digital device is not yet deemed unsuitable for learning. Care has been taken to ensure that where pen and paper are the best tools for understanding a concept and practising associated questions, students' learning is not compromised by the use of a digital device. The rigorous quality control procedures in place to catch any errors, inaccuracies and ambiguous or confusing presentation of questions in the online platform mean that teachers can trust the content provided by Sparx and don't need to spend time correcting content errors. In 2019, we conducted a teacher workload survey in schools using Sparx (Szmaragd & Welbourne, 2019) in which 90% of the 80 respondents stated that they either agreed or strongly agreed that Sparx has reduced their overall workload, with the median of the reported time saved being 30 minutes per class per week.

Finally, Sparx also provides teachers with paper-based half-termly tests suitable for use with the Sparx scheme of learning. Regular paper-based tests ensure students are prepared for sitting written exams in timed conditions in the future. Data from these test results can be sent to Sparx for a full analysis of performance including common wrong answers per class and a fully anonymised comparison of each Sparx school's standing, which is then returned in the form of a report to schools typically within 1-2 weeks of receiving exam data. Together with homework completion rates for the half-term also included in these reports, the teacher can use the information to better understand the progress of their class and choose the most appropriate intervention to help struggling students.

For schools

There are three main benefits for schools in using the Sparx learning platform. Firstly, schools are kept fully informed of the progress of each of their maths classes, in terms of test performance and homework completion rates, so that extra support can be provided to boost progress where needed. Currently, the average cumulative homework completion rate in schools using Sparx since April 2017 is 95.1%. Secondly, the lessons provided by Sparx ensure the quality of maths teaching is high, consistent and as similar as possible across all classes even when taught by a supply teacher. Also, due to the substantial reduction in teacher workload when using Sparx (eliminating the need to mark homework and analyse test data and greatly reducing the time required for lesson planning), teachers have more time available to work collaboratively with each other and with the school leadership to make decisions on where to focus resources and to seek and implement new ways to help the most struggling students.

The Education Endowment Foundation has published guidelines for schools on how to improve maths learning at Key Stage 3 (The Education Endowment Foundation, 2017), in which improving students' procedural and conceptual knowledge, student motivation and targeted support are particularly emphasised. Due to the design and delivery of Sparx lessons and homework, and the analysis of data that allows Sparx to provide schools with deeper insights into student progress and engagement with maths, Sparx provides schools with the opportunity to successfully implement these guidelines.

Summary

Sparx Maths is an online maths learning platform that has been designed in light of both evidence from academic research on how students learn and seven years of student observation by the developers working closely with partner schools to monitor student engagement with maths and what aids students' understanding of difficult concepts and procedures. The knowledge derived from both these observations and educational literature has played an integral part in shaping every design choice in the Sparx platform. When building a research-based learning platform, it is essential not only to have awareness of the consensus amongst the educational research community on every aspect of learning, but also to conduct research where a question is as yet unanswered or where a consensus is lacking. In an era of rapidly emerging educational technology, it is this two-pronged approach to the design of Sparx Maths that makes it unique amongst other digital learning platforms.

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