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Mindspark: Improving Educational Outcomes in India

As 2017 opened, Sridhar Rajagopalan, cofounder of the Ahmedabad-based company Educational Initiatives (EI), and Pranav Kothari (MBA 2011), Vice President at EI, reflected on the progress that their company had made towards the goal of transforming education throughout India by changing how students learn. Launched in 2009, Mindspark was a flagship product of EI, a computer-based adaptive learning program that used finely-graded questions and adaptive logic to help students learn mathematics and language. Mindspark personalized the curriculum of individual students according to their prior knowledge and misconceptions, and it encouraged "learning by doing" instead of mechanical instruction based on the memorization of facts.

In 2016, researchers associated with the Abdul Latif Jameel Poverty Action Lab (J-PAL) at the Massachusetts Institute of Technology (MIT) completed a rigorous evaluation of Mindspark and found that it was "highly cost-effective," with results suggesting that students could experience almost a full grade-level increase in mathematics by undergoing the program in 4.5 months at a cost that was less than 70% of the government's spending per child in public education.[1] In India, where only 51% of students in grade 5 could perform subtraction at a grade 2 level, Mindspark offered promise in generating meaningful improvements in students' educational outcomes.[2]

Since its launch, Mindspark had become a leader in market share in private schools across India, growing from about 6,000 users in 2010 to 80,000 in 2017. However, Mindspark's presence in the government school system had remained very small,[a] restricted to a few pilots in schools serving low-income students, funded by foundations and corporate social responsibility donations from firms. However, those programs had been limited in reach, and some had ended once the funding stopped. Now, Kothari and his team were considering how to leverage their market position and strong results to make Mindspark a sustained presence in the government school system.

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[a] In the U.S., the term "public school" referred to schools funded and run by the government. However, in India, many independent, private schools had the term "public" in their names, such as the privately run Delhi Public Schools. Therefore, to avoid confusion, in this case the term "government school" will refer to the free schools funded and run by the government; and the term "private school" will continue to refer to the privately owned, fee-paying schools.

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Already, the state governments of Chhattisgarh and Rajasthan were launching Mindspark pilots, each in 5 government schools. Although India's state and central government avowed strong desire to increase the use of information and communication technology (ICT) in the education sector, Kothari still faced a number a financial, operational, and policy challenges. For example, there was interest from some officials to launch Mindspark at scale in thousands of government schools, serving hundreds of thousands of children, in one stroke. Should EI pursue such an exciting opportunity, and if so, how would the company manage the demands of such rapid growth? Kothari recognized that only a small proportion of government schools had the adequate infrastructure to enable the ideal Mindspark deployment, such as physical space, reliable hardware, and Internet connection. How should Kothari think about implementation targets and strategies, and which partners might contribute to Mindspark's success in the government system? In addition, how should Kothari manage the training and attitudes of teachers towards education ICT, and how should Mindspark's impact be assessed going forward?

Education in India

Under Article 21-A of the Indian Constitution, children between the ages of 6 and 14 were entitled to free and compulsory education.[3] Primary school, free for all, lasted from kindergarten to grade 8. Secondary years (grades 9 to 12) were free or low-cost, depending on state policy.[b] Those passing a rigorous Higher Secondary Examination in grade 12 could continue to undergraduate programs that lasted between 3 and 5 years.[4]

Over the past two decades, a number of government programs had greatly expanded access to education. In 1990, the net enrollment rate of primary schools was 77%; in 2003, 83%; and in 2013, 92%. The literacy rate of male youths (ages 15-24) rose from 74% in 1991 to 92% in 2015; and that of female youths (ages 15-24) rose from 49% in 1991 to 87% in 2015.[5] As of 2015, 98% of households could access a primary school within 1 kilometer of walking distance, and 92% could access an upper primary school within 3 kilometers.[6] With over 1.4 million schools (government and private combined) and 253 million students, the Indian K-12 system was the largest in the world.[7]

Despite India's progress in improving access to education, many challenges remained. Of note, the number of student enrollments dropped drastically as the level of education increased. Nationally, about 27% of children dropped out at the primary level; and 49% at the secondary level. Since 2009, central law mandated that students would be automatically promoted each year until grade 8. This no-fail policy meant that in any given classroom, the knowledge levels of students could vary significantly. Instruction delivered to students who had fallen behind too much would be "wasted" because they were not yet ready to learn the more difficult material.

The government education system faced many challenges. In December 2016, 18% of all teaching positions in government primary schools and 15% of all teaching positions in government secondary schools were vacant, representing a shortage of about one million teachers.[8] Nationally, teacher absenteeism was about 25%(meaning, on average, teachers showed up to teach only 3 of every 4 class days), with higher rates in poorer and rural areas; and training and support for educators were often lacking or inadequate.[9] A large majority of teachers had no ICT training, and many schools did not have even one teacher with ICT experience. Furthermore, the government school system had relatively poor infrastructure. In a study of over 15,000 government schools in 2014, only 20% of schools had

[b] Government secondary schools were almost always free, but most state governments operated a small number of these free schools by themselves. Many secondary schools were run by trusts that were subsidized and charged fees.

computers, 65% had useable toilets, 56% had useable girls' toilets, 76% had drinking water available, and 78% had library books. On any given day in September, October, or November, just 71% of enrolled students were attending school.[c] In rural India, only 24% of children in grade 3, 48% in grade 5, and 75% in grade 8 could read at the grade 2 level; and only 25% of children in grade 3 and 51% in grade 5 could perform basic subtraction, a grade 2 skill.[10]

The poor quality of government schools in many regions had led numerous parents to send their children to private schools. India's private school system accounted for 25% of all K-12 schools and enrolled 100 million (40%) of the nation's 253 million students.[11] By comparison, only 9% of K-12 students in the U.S. (5 million out of 56 million) were enrolled in private schools.[12] Private schools were not limited to the wealthy and varied in price, including low cost schools ($15 per month, or even less with subsidies).

Evidence suggested that India's private schools had better facilities than government schools. One study found that while only 7.9% of government schools met infrastructure standards, 30% of private-and-aided schools (private schools that received some government funding) and over 50% of private-and-unaided schools met the same standards.[13] Some studies had found negligible differences in the mean educational outcomes between affordable private schools (costing around $15/month) and government schools, but the mean educational outcomes of high-fee private schools (costing between $30 and $120 per month) exceeded those of the other two categories. These studies did not adjust for differences in household wealth among the students, and the quality of education varied widely across and within regions in each school category.[14] In addition to private schools, parents often paid for supplemental help to improve educational outcomes. In rural India, over 20% of children in grades 1 to 8 attended paid supplemental classes.[15]

The Founding of Educational Initiatives

Educational Initiatives was founded by Sridhar Rajagopalan, Venkat Krishnan N., and Sudhir Ghodke in Ahmedabad, India in 2001. The three cofounders were graduates of the Indian Institute of Management Ahmedabad, one of the most prestigious business schools in India. In 1996, just a few years after completing their MBAs, the three worked together to found the Eklavya School, a K-12 private English-medium school that provided students with comprehensive development in academics, sports, fine arts, and music. Going against the mainstream pedagogy that emphasized repetition and memorization, the school used innovative techniques to make the learning process enjoyable, encouraged students to develop their individual talents, and sought to instill a "sense of purpose" in each child.[16,]

According to Ghodke, "the Eklavya School was about social change and social impact… we were three crazy guys doing some crazy things." In particular, the school sought to achieve excellence, while benefiting "every child;" 25% of students were funded by scholarships. To build a community, students were drawn only from within a certain radius of the school, and educators conducted home visits. Children from all backgrounds attended class and played sports together. Ghodke emphasized that the cofounders "took a very aggressive stance on integration." For example, all students had to use the bus, and children from wealthy families who missed the morning bus were not allowed to arrive in a private car. Although there was some initial resistance from both wealthy and poor parents, the cofounders were ultimately successful in convincing the families that their children would receive

[c] These statistics varied widely across states. For example, in the state of Uttar Pradesh, only 50-59% of children were present on a given day, but in the state of Tamil Nadu, 90-99% of children were present.

high-quality, inclusive education. Today, the school continued to provide an integrated education. It occupied a 35-acre campus, enrolled 1,300 students, and employed 110 full-time teachers.[17]

In 2001, the three cofounders viewed Eklavya School as a success, but also only "a drop in the ocean." EI was founded to create large-scale change in the education system by ensuring that "every child learns with understanding" and "making a difference in education through personalized learning."[18] The company specialized in educational research and assessment, and its first product was an assessment tool called ASSET (Assessment of Scholastic Skills through Educational Testing). Instead of simply testing for children's knowledge of facts or their ability to do textbook problems, ASSET was rigorously designed to measure whether students truly understood the underlying principles taught in their mathematics, language, science, and social science curricula (**Exhibit 1**). A central goal was to identify students' misconceptions and to uncover the reasons behind students' difficulties in learning certain concepts. According to Rajagopalan, EI's theory of change was that by demonstrating the gaps in students' learning, educators could and would make changes to address those gaps.[19]

ASSET had been marketed as a tool to help students understand their individual strengths and weaknesses, to enable schools to benchmark their performance, and to provide teachers with insight on how to structure their instruction. Since its founding, EI had administered ASSET in over 3,000 schools in India (with a small presence in the United Arab Emirates, Kuwait, Singapore, and the U.S.), and today over 350,000 students took ASSET every year. In addition to ASSET, EI also developed other types of assessment tests for both children and teachers and provided consultancy services to help educators improve student outcomes.[d] In total, since 2001 EI had assessed about 14 million students.[20]

From its second year, EI had become profitable and required no external financing. The company was initially funded by a small group of family, friends, and angel investors; and the three cofounders held a majority stake. From the beginning, the cofounders intended to work with children from low-income households to improve the quality of education for all. They actively engaged with philanthropic and development organizations in joint projects to analyze India's education sector and to develop pedagogical recommendations. Some of EI's clients included the World Bank, UNICEF, USAID, various universities and foundations, state governments in India, and foreign governments.

In November 2006, EI's efforts made the front page of *India Today*, one of the nation's most popular news magazines. The cover story was titled "What's Wrong with Our Teaching?", and it reported the survey results that EI had conducted with the support of a CSR initiative of the technology company Wipro. In the survey, 32,000 students in 142 of India's top private schools were tested on their understanding of English, mathematics, and science. The researchers found that 1) because students were focused on rote, mechanical learning, they performed very well on conventional textbook questions; 2) however, students performed poorly on questions that tested for the understanding and application of core principles; and 3) compared to students of the same grade from 43 other countries, the surveyed students performed far below average in mathematics and science. The article generated a great deal of public interest in EI's work, and it exposed a number of decision-makers to the idea that educators must focus more on guiding students to understand and apply their knowledge rather than just teaching the facts.[21]

Similarly, in 2009, with sponsorship from Google, EI conducted a benchmarking study of 101,643 children in the government schools of 18 Indian states and found that students could handle "procedural" questions but scored poorly in more atypical, conceptual, or application-based

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[d] ASSET was a product developed primarily for private schools. Assessments for government schools were conducted under different product names.

questions.[e] The study also found that students frequently carried misconceptions from previous grades into their current studies, and that almost 40% of students in grade 8 did not have grade 4 competencies. From this research, EI recommended that the government set targets on the quality of learning outcomes; increase the number of low-stakes diagnostic testing in order to increase feedback for students, parents, and teachers; use benchmarking among schools; build systems to track the progress of individual students; and move away from rote learning towards more innovative, interactive pedagogical methods that cultivated lifelong learning.[22]

Mindspark

Using the millions of data points collected from student assessments conducted in previous years, EI began to develop Mindspark in 2008. Mindspark was a computer-based, adaptive learning program that allowed students to learn and practice new topics in math and language. It was meant to supplement, not replace, classroom instruction. Rajagopalan expressed that the inspiration for Mindspark had come from the EI team's years of unraveling patterns in the misconceptions and roadblocks that children frequently experienced, and from the slow pace of change in the education sector despite EI's efforts in highlighting and explaining the prevalent pedagogical problems.

Intelligent Tutoring for Students

Mindspark could be run from a browser on a computer or a tablet and required at least a periodic Internet connection.[f] Mindspark had a number of features designed to help students learn. First, Mindspark used *finely-graded questions*, which encouraged "learning by doing" by progressively challenging students with questions of increasing difficulty. Second, the learning process was very gradual and used *adaptive logic* to ensure that students truly absorbed a concept before advancing. For example, an incorrect response to a question would lead students to an easier question coupled with interactive animations or helpful tips and explanations, whereas a correct answer would lead to a more challenging question. Thus, Mindspark enabled the individualization of learning based on students' actual academic levels. Third, Mindspark provided immediate *intelligent responses* to help students understand why certain answers were marked right or wrong. Detailed feedback was provided to identify the errors that students had made. Fourth, *voiceover support* in mathematics was provided in certain rural and municipal school deployments, where low levels of reading comprehension often hindered children's ability to understand the content. Fifth, Mindspark provided interactive modules called *remedial*s that helped a child learn a concept through a combination of instruction and integrated quizzes (**Exhibits 2 and 3**).[23]

To further enhance comprehension, over 60% of Mindspark's content had graphics or animations, and students could play a number of educational games to practice their skills. And to provide encouragement and motivation, Mindspark had an elaborate rewards and recognition system that gave points called "Sparkies" based on certain learning behaviors, which included 1) good performance from answering questions correctly; 2) consistent use of Mindspark; 3) spending time to read the explanations that followed each question; and 4) persistence in completing topics. Students' total Sparkies points were displayed on their homepage, and they could earn "badges" or "level up"

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[e] An example of a procedural question would be: "Give the answer of 43 x 2." About 67% of students answered this question correctly. An example of a conceptual question would be: "Fill in the blank: 3 x __ = 3 + 3 + 3 + 3." About 30% of students answered this question correctly.

[f] An offline version was released in 2014, but it nonetheless required an Internet connection for content updates, the uploading of student data to track progress, and certain personalization features.

depending on their Sparkies count and types of milestones reached **(Exhibit 4)**. Features could be activated at the classroom level that encouraged monthly competition among students, whereby the top students would be recognized based on their speed, accuracy, and complexity of questions solved. Furthermore, an "Emote Toolbar" on the side of the screen with the buttons *Like*, *Dislike*, *Excited*, *Bored*, and *Confused* allowed students to provide emotional feedback to the system, and a *Comment* button allowed students to write direct feedback to the EI team. Mindspark's developers used this data to modify the content and sequencing of questions and to conduct research on the connection between emotional states and educational outcomes.[24]

Support for Teachers

The Mindspark program covered mathematics content from grades 1 to 10. The mathematics content was aligned with the syllabus requirements of various government authorities, state boards, and international curricula such as the International Baccalaureate (IB) and Cambridge International General Certificate of Secondary Education (IGCSE). Teachers were given full control to customize the Mindspark curriculum for their students (**Exhibit 5**). In an implementation, a teacher could teach a new topic in class—say, the addition and subtraction of fractions—and then "activate" that topic in students' Mindspark accounts. Students would then be given time to log onto Mindspark and practice the topic, and the system would generate detailed progress reports for the teacher on students' performances (**Exhibit 6**). Using this report, the teacher could assess comprehension and adjust future lesson plans to address common problems, and decide whether certain students required individualized attention. The teacher could summarize the topic by providing additional instruction and discussion as necessary. Using the Mindspark system, the teacher could also generate monthly reports on individual students that could be shared with parents. In some deployments, parents would be given a login account to track the progress of their children. Finally, the EI team provided training for teachers and students, and further support was available by phone or email.[25]

The Implementation of Mindspark

Since its launch in 2009, Mindspark had been primarily deployed in private schools (**Exhibit 7**). In 2009, Mindspark charged clients about $30/child/year. In 2010, a tablet version was offered. In 2013, developers ported the content to HTML5 so that Mindspark would be device-agnostic (requiring only Internet Explorer, Mozilla Firefox, or Google Chrome to run). In 2014, an offline version was created, which required only periodic internet connections. In 2016, EI launched a Mindspark product for English reading and language for grades 4 to 9.[26,27]

All software development was performed in-house, which included the creation of questions, graphics, animations, and user experiences. According to Kothari, the EI team spent considerable time applying pedagogical concepts and behavioral psychology to the workings of Mindspark. The team performed critical analyses to understand which questions worked and why, and in-house experts designed and sequenced all the material. Machine learning was not used to automate or "optimize" the sequencing of questions, but the team had been exploring its potential and was looking for the right talent to incorporate machine learning into the backend. Employees often took a sizeable pay cut to join the mission-oriented firm. As of March 2017, EI had about 220 employees, of which about 40 were IT staff and about 80 composed the sales team (for all of EI's products).

As of 2017, Mindspark was sold to private schools for $30 to $40/child/year; and online retail versions were offered for any child to use at about $25 for 3 months or $75 for 12 months. Mindspark used Amazon Web Services to provide flexible bandwidth availability. For desktop deployments, Mindspark recommended at least a Windows 7-operating computer with 2 GB of RAM. Mindspark also worked smoothly on an iPad (iOS 6 or above), Chromebook, and tablets (Android 4.0 or above).[28] In India, a low-cost desktop with a monitor could cost about $150, a Chromebook $100, and a tablet $50.[29]

In a typical implementation of Mindspark, an EI team would begin by conducting a needs assessment for the school. The team would then perform an infrastructure check, understand how Mindspark should be customized, and make a presentation or sales pitch to the principal and teachers. If all parties determined that Mindspark would be a good fit, the EI team would begin implementation either in select classrooms as a pilot program or directly throughout the school as a full-scale launch by providing registration, training, and orientation to teachers and students.[30]

Although private schools accounted for the great majority of Mindspark sales, the cofounders had worked extensively with various funders to expand the use of Mindspark in low-income areas and government schools. The first pilot of Mindspark was conducted in 2008 with the support of the Suzlon Foundation in a village of the Ratlam district of Madhya Pradesh. The second pilot was conducted in 2009 with the support of the Michael and Susan Dell Foundation, with McKinsey & Co. as an observer. Both pilots were small, lasting only a few weeks with less than 50 students in each deployment.

The next Mindspark project was considerably larger. In 2011, with financial support from the company Torrent Group, EI deployed Mindspark in 21 government schools in the state of Gujarat, which brought the number of government school users to over 2,000. The original Mindspark product had taught mathematics using English, the language of instruction for high-fee private schools and most affordable private schools. However, many government schools and some affordable private schools taught in the state's vernacular language, Gujarati. Torrent and EI invested resources to develop a mathematics product in Gujarati. In addition, because children with poor reading comprehension faced challenges in understanding math questions, a language product to teach Gujarati was also developed.

This project with the Torrent Group lasted from 2011 to 2016. Over this period, "treatment schools" experienced a 55.1% increase in assessment test scores, compared with "control" government schools of 27.3% and private control schools of 12.5%.[31] The Torrent Group provided and maintained the hardware, and Mindspark provided continuous teacher support to help with curricula design and the integration of Mindspark in class. One government school teacher found that Mindspark was particularly useful in helping her manage a classroom of children with different levels of learning. First, she used Mindspark to assess the actual grade levels of her students and used the generated reports to categorize them into groups. Then, the teacher delivered instruction to one group of students while having another group use Mindspark on the computers. Gradually, she recognized that students who had started on a lower level were able to catch up. The teacher also described that parents had become "very emotional" upon visiting the school and watching their children using computers. Furthermore, one government school principle noted that student attendance had significantly increased since the introduction of computers and Mindspark.[32]

Though the Gujarat government schools were enthusiastic about Mindspark, the Torrent Group in 2016 switched partners for their CSR initiative. The new partner provided software for a one-time fee (as opposed to Mindspark's monthly subscription fee) and had subjects other than math and language. Although this product was neither personalized nor adaptive, it helped teachers with *curriculum delivery* by providing technological support in delivering the required lessons of state-approved curricula. Over the past couple of years, the state government of Gujarat had approved the purchase of smartboards for some government schools, which were essentially large touchscreen boards that enabled teachers to project graphics and other materials during class. The Torrent Group's new partner included a smartboard product that was fully integrated with textbooks (essentially a "digitized" textbook), so that teachers could deliver textbook material using the smartboard and assign practice questions on the computer that were aligned with the curricula. While a number of teachers liked the new products, others still preferred Mindspark, and the Torrent Group's CSR team was actively reviewing the outcomes and user experience of the new products.

The Mindspark Centers

EI's team had found that Mindspark implementations in rural areas often fared better than those in urban areas, especially when the close-knit nature of a community fostered greater communication among principals, teachers, and parents. Because Mindspark required behavioral and pedagogical changes, having a supportive community around students was important to success. In addition, Rajagopalan noted that urban schools faced more binding resource constraints due to issues of overcrowding, funding, and teacher shortages.

Despite these challenges, Rajagopalan recognized that urban cities contained some of the areas that needed innovative education technology the most. Thus, in 2012 Mindspark developed so-called Mindspark Centers located in the urban slums of Delhi, in order to expand access to government school students. Independent of local schools, the Centers were essentially rooms filled with computers that allowed students to use Mindspark on their own time outside of class (**Exhibit 8**). Mindspark Centers operated a popular after-school program in which students came to the Center for 90 minutes per day, 6 days per week. During each of these 90-minute visits, students used Mindspark on the computers for 45 minutes, followed by 45 minutes of instruction from a teacher in groups of 12-15 students. Although Mindspark Centers were funded philanthropically, donors believed that charging a modest fee was necessary to encourage actual use of the product (some academic research had demonstrated that cost-sharing could effectively reduce wasted resources in philanthropic projects). The Centers therefore charged each student about $3 per month for the after-school program. Total fee collections amounted to 10% of the actual costs, which included rent, employee salaries, utilities, hardware, and software; the balance was funded by philanthropy.[33]

By 2013, there were 5 Mindspark Centers in Delhi that had capacity to serve about 2,000 low-income students per year. From 2015 to 2016, academic researchers affiliated with MIT's J-PAL conducted a randomized controlled experiment to test the effectiveness of the Centers' after-school program. In Delhi, government schools spent about $22/child/month, and students spent 240 minutes per week studying math and Hindi. The unsubsidized (total) cost of the Mindspark Centers' after-school program was $15/child/month, and students spent 180 minutes per week studying math and Hindi. By comparing the value-added in educational outcomes, the researchers found that the Mindspark program delivered greater learning at lower financial and time cost, because "relative to the control group, [Mindspark students] experienced twice the test score value-added in math and 2.5 times that in Hindi during the study period of 4.5 months." Translated in terms of grade-level outcomes, students in the Mindspark program jumped almost an entire grade level relative to the control group. The researchers also estimated that if Mindspark were deployed in 100 government schools, the unsubsidized cost of the program would drop to $2/child/month; for 1,000 schools, the cost would be $1/child/month; at the scale of an entire state, the cost would be under $2/child/year. Despite these favorable results, the study cautioned that the efficacy of Mindspark might be different in different conditions.[34]

The Mindspark Centers were originally funded by the Central Square Foundation in 2012, which was founded by the prominent Indian private equity investor Ashish Dhawan (MBA 1997). Because the medium of instruction in Delhi's government schools was Hindi, the Central Square Foundation also partly funded the development of the Mindspark math and language products in Hindi. One of the foundation's goals was to fund early stage, high-risk ideas; and after one year of funding as a proof-of-concept, the foundation did not renew the Centers' funding in 2013. The EI team decided to self-fund the Centers for a few more months. Then, in April 2014, the Tech Mahindra Foundation agreed to provide funding for 5 years. However, in March 2015, that funding also stopped as the Tech Mahindra Foundation decided to divert resources into another larger philanthropic project in education. EI obtained funding from another grant-making organization, Porticus Asia, for the period April 2015 to December 2015, after which EI decided to self-fund the Centers again.

After the conclusion of the J-PAL study, in March 2016 all 5 Mindspark Centers in Delhi, which had served 5,000 low-income students since inception in July 2012, were shut down due to lack of continued philanthropic funding. The EI team could not find a long-term charitable partner—it cost about $40,000 per year to operate one Center—and had been investing significant resources into searching for funding and managing the Centers. In addition, the EI team had begun to pivot their government school strategy from philanthropy to selling directly to the state governments, which the team felt was the more scalable and sustainable option. Kothari recalled the very emotional day the Centers' closed, as they had been one of his most important projects since joining EI. Coincidentally, the lead researcher of the J-PAL study called Kothari that same day and informed him of the study's strong results.

ICT and the Government

In 2017, Mindspark was one of many ICT solutions in the education sector in India. In recent years, the use of technology in education had become an increasing focus of the Indian central and state governments. Prime Minster Narendra Modi, for example, had discussed the need for "digital classrooms" in a number of speeches in India and abroad. However, educators often had difficulty choosing the best technologies to improve educational outcomes: while costs were relatively easy to discern, benefits were not.[35]

The successful deployment of education ICT required several inputs, including physical space for computers, well-maintained hardware, a well-selected array of software, maintenance contracts with a technology firm, and usually, Internet and Wi-Fi connectivity. A few comprehensive, integrated ICT companies provided "hand-holding" services in building such ICT capacity for schools. For example, the company Educomp Solutions converted regular classrooms into digital classrooms by providing hardware (computers, projectors, and smartboards), software, maintenance contracts, teacher training, and curriculum design. According to Educomp:[36]

> Educomp smartclass brings about a complete transformation in classrooms. The Science teacher while explaining how a DNA replicates is able to show the class a 3D animation of the DNA replication process on a large screen. She can explain the fine points of the process, zoom in to show the relevant visuals, freeze and annotate when and where she needs to emphasise… Towards the end of the class, every teacher displays a set of questions on a large screen, every child in class gets ready to answer the questions with their personal answering device… Students click the answers, instantly, teachers are able to get a score sheet for every child in class. She ends the class re-teaching the parts of the lesson that were not understood well by class.

Kothari and Ghodke were critical of Educomp and expensive hardware such as smartboards, feeling that the pedagogy of their use had emphasized curriculum delivery over actual material absorption. Smartboards and other types of hardware innovations were "fancy" products that private schools could use to impress the fee-paying parents, but the EI team did not see hardware innovations by themselves as effective tools in improving educational outcomes. Ghodke noted that he had "never" considered entering the smartboard business.

A few other companies also provided ICT implementation on a turnkey basis, by setting up hardware that came pre-installed with relevant software; and a number of firms provided individual products that spanned a range of functions, such as performance assessments, student progress tracking, and various learning software. There were various companies that helped teachers with curriculum delivery by digitizing textbooks and providing "curriculum in a box" that included worksheets, activities, and smartboard presentations. However, there were no software products other than Mindspark that offered both personalized and adaptive learning. One potential competitor in the space of personalized learning software was Khan Academy, a nonprofit organization that provided online education for free. In 2015, Khan Academy had developed a product that taught mathematics in Hindi, which consisted of assessment tests to determine students' level of knowledge, pre-recorded instructional videos, and practice problems. This product had a small presence in India, and there were no studies that demonstrated its effectiveness in improving learning outcomes.[37]

How effective were these ICT implementations in producing actual learning outcomes? Numerous studies had been conducted to test the effectiveness of various hardware and software interventions, and the results were quite mixed. A number of studies had found that simply providing hardware in classrooms led to no or little improvement in language and math skills; and studies conducted on the impact of software deployments found that the effectiveness varied considerably depending on the type of software deployed, the research and pedagogical techniques that the developers used, how the software was used by students, and how teachers interacted with the software in classrooms.[38]

Government Funding and Procurement

In India, the central government released so-called Five-Year Plans that outlined the nation's economic and social goals, and the central government's funding for various programs. Under the current scheme for ICT expenditures in government schools, the central government provided about $10,000 per school (non-recurring) for ICT capital expenditures and another $4,000 per school per year (recurring for 5 years) for operating expenditures. These expenditures were budgeted to allow for the purchase and operation of 10 computers and a few other hardware needs, such as a projector and a modem (**Exhibit 9**).[39] However, most government schools had class sizes of 30 students or more, which meant that a lab with 10 computers was not sufficient for individual usage. As Kothari explained, three children could not be expected to sit in front of one computer to work on Mindspark questions, though it did happen in some deployments. Due to increased awareness, some states were now purchasing 20 to 25 computers with the same budgets by reallocating certain items.

Schools that sought funding for ICT implementation required approval from the state government, which assessed schools by infrastructure, student accessibility, and teacher capabilities (**Exhibits 10 and 11**). Once a government school was approved for ICT implementation, teachers and principals had very little power in determining which technologies to purchase, as the state government was primarily responsible for managing the procurement of technology. Traditionally, state governments used the BOOT (build-own-operate-transfer) model of ICT procurement. Under this model, the government would procure all ICT components (hardware, software, maintenance, service, etc.) from a single integrated vendor, who would manage the entire ICT implementation of designated schools. Educomp, for example, was a common bidder of government tenders issued under the BOOT model. After operating the assets for a specified amount of time (often 5 years), the vendor would hand over the hardware and software to the school. Some government officials found the BOOT model appealing because having a single vendor meant fewer challenges in coordination, and the winner of a BOOT tender was often the company that offered to implement programs at the lowest cost. However, critics argued that under this model, the government gravitated towards the cheapest hardware vendor irrespective of the quality of software or the teacher support provided. In addition, the winning vendor had an incentive to cut costs during the duration of the contract, and at the end of the contract, much of the hardware would have become outdated.[40]

A second model adopted more recently in India was known as the "direct" or "outright" model. In this model, the state government procured hardware and software components from different vendors to create a more customized package. Because a central vendor did not manage the integration of parts, the state's department of education, school administrators, and teachers coordinated among themselves and with vendors to optimize the ICT implementation. Under the direct procurement model, the installation and maintenance of hardware and software were often done by the teachers themselves. Although this model required greater effort and initiative from school administrators and teachers, proponents argued that the direct model enabled a higher level of technology integration into classroom curricula than the BOOT model, because teachers had to be involved with the customization of technologies.[41] In recent years, some state governments had been slowly switching from the BOOT model to the direct procurement model, though it was still unclear which model produced better educational outcomes. For example, in Rajasthan, the BOOT model had been used from 2008 and 2014, but the direct model was used from 2015 onwards.

According to Rajagopalan, governments had traditionally placed more emphasis on procuring reliable hardware than on making sure that the installed software actually enabled better learning. Although there was a clear directive from the central government to implement ICT into government school classrooms, that often translated into the building of a computer lab without a clear strategy for integrating relevant software into students' curricula. In addition, according to a government official in the state of Chhattisgarh, previous ICT implementations in Chhattisgarh's government schools had not been very outcome-oriented. The building of computer labs often came with much excitement from the school and community, but there were few analyses on the effectiveness of technology on educational outcomes. According to another government official in the state of Rajasthan, traditional assessments such as the grades from midterms and annual exams had been the primary means for evaluating the learning outcomes of ICT implementation. Finally, as the central government's ICT budget demonstrated, there had been a greater focus on allocating resources for hardware than on software; and state government officials were often reluctant to stray from line item budgeting to reallocate more money towards the purchase of software.

Opportunities and Challenges Ahead

Driven to make Mindspark available to children from low-income families, the EI team had sought philanthropic funding and invested much time and resources into developing the Mindspark products in Gujarati and Hindi for government schools. However, as the philanthropic model proved unsustainable, Kothari found that there was essentially "no market" for the Gujarati and Hindi products to be deployed at scale unless EI started working with the state governments.

At the beginning of 2017, EI was preparing to launch pilot programs to implement Mindspark in a handful of government schools in the states of Rajasthan and Chhattisgarh.[g] The Chhattisgarh government had released a tender for an integrated vendor that would provide hardware, software, and maintenance, for which EI did not make a bid because the tender required substantial investments

[g] The vernacular language of both Rajasthan and Chhattisgarh was Hindi.

in hardware and EI did not wish to take the risks associated with typical payment delays from the government. As of March 2017, the situation was still evolving, and the winning bidder of the tender had yet to be determined.

In addition to Chhattisgarh, there was also interest from other state governments to deploy Mindspark at scale in thousands of schools at once. Rajagopalan noted that government officials had become increasingly drawn to Mindspark because of media attention on the effectiveness of the product and because their own children, many of whom were enrolled in private schools, had positive experiences with the product. Kothari believed that his team was capable of rolling out Mindspark at scale. There also appeared to be adequate public funding, as Rajasthan spent about $170 per child per year and Chhattisgarh spend about $180 per child per year in operational expenses in primary government schools. Mindspark, if deployed at scale, could be priced at as low as $1 per child per year (not including hardware costs which would be another $5 per child per year).[42]

However, as Kothari looked ahead, he recognized that there were a number of details that needed to be worked out. First, school administrators and teachers had to be convinced that Mindspark was effective. After all, Mindspark was a cloud-based software product, not a large, visible touchscreen smartboard which school principals could easily showcase to parents. Kothari felt that in general, parents tended to understand and pay for better curriculum delivery instead of "learning" and "absorption"; and that parents tended to equate the quality of learning with the quality of inputs, such as tangible infrastructure (hardware and air conditioning in classrooms) and policies that required children to wear uniforms. How could EI make Mindspark's impact more "visible"?

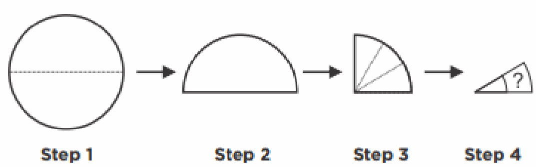
Second, many government schools faced infrastructure issues such as lack of electricity and poor (if any) Internet connection. How should Mindspark navigate these challenges, and what was the operational model of deploying Mindspark at such a large scale in government schools? Third, how would EI manage the orientation and training of educators in a mass deployment of Mindspark? In a pilot study conducted with USAID on 500 students from 2013 to 2014, it was found that "some teachers became disengaged because students were learning on their own" and that "reactions from teachers were mixed." The USAID report recommended that having the principal's buy-in was critical to Mindspark's success, and that teachers required support to understand how to integrate Mindspark into their curricula.[43] Kothari noted that a mindset change among every stakeholder in a school was required for teachers to use Mindspark as an effective teaching assistance tool. Given all of these concerns, was EI heading in the right direction in their push to enter government schools, or should they consider alternative strategies?

Exhibit 1 Example of How an ASSET Question Detected Misconceptions

Sample ASSET Question

The figure below shows that a circular piece of paper is folded along the dotted lines in steps 1, 2 and 3 to get the final shape.

The dotted lines divide a shape into equal parts.



What is the measure of the angle marked in the final shape?

A. 15°
B. 30°
C. 45°
D. 60°

The question tests the basic understanding of the measure of a right angle. Performance data shows 41% of students who attempted chose option A, whereas the correct answer is option B. This reveals the widely prevalent incorrect understanding about the concept of right angle.

Option	Option	Percent*
A	15°	41%
B	30°	39%
C	45°	13%
D	60°	07%

*Percentage of students who chose different options

Source: Company documents. Also available at: http://www.ei-india.com/wp-content/uploads/2016/07/ASSET_V2_2016.pdf, accessed March 2017.

Exhibit 2 Sample Mindspark Questions

Our questions are specially designed to help students discover for themselves the 'why' behind the Maths they do. The questions are carefully granulated at a skill level, with each question being just a little more difficult than the previous one. Our adaptive logic uses this gradation to deliver to the child those questions that are appropriate to his or her ability levels. Based on a child's answer to one question, Mindspark will determine whether the next question should be easier, more difficult, or another question of the same type, to ensure that learning happens in an efficient, productive manner.

Question type 1

Kiran and Aamir buy a cake. Kiran says he wants 1/3 of the cake, and Aamir says he wants 1/4 of the cake

What is the MINIMUM number of equal parts in which they should divide the cake to make this possible?

A 3   B 4

C 7   D 12

Figure 1: Introducing the concept of LCM without explicit mention of the term

- Our questions test known concepts without explicitly introducing terms
- Such questions build understanding while preventing learning by rote
- The careful gradation among the questions helps a child see the connections between the various concepts and topics that he or she is exposed to

Question type 2

- The options in the multiple choice questions are designed to ensure that those knowing a concept can be distinguished from those not knowing a concept.
- It moves one level deeper to determine the reason behind why the child is struggling with certain questions, offering him or her targeted help to solve whatever the issue may be.
- Mindspark aims to bring about all-round knowledge on a particular topic before moving on to the next one.

Which division fact matches the picture below ?

A 10 ÷ 2   B 10 ÷ 10   C 5 ÷ 10

Figure 2: The questions ensure that one understands when to perform a particular operation, instead of just ensuring that one can solve it.

Source: Company documents. Also available at: http://iis.stkabirschool.com/pdf/Mindspark%20brochure.pdf, accessed March 2017.

Exhibit 3 Intelligence Responses to Errors Made by Students

Solve for x

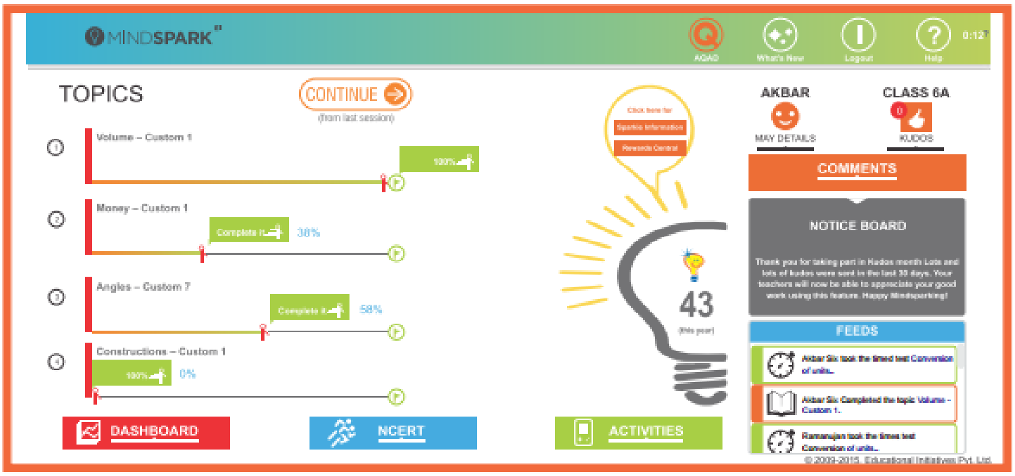
$3(x + 7) = 15$

Hide	$3x + 7$	=	15	You seem to have made an error in expanding the term: $+3(x + 7)$
Hide	$3x$	=	15	Please check the term on left side of the equal to sign.
Step 1	$3x + 21$	=	15	✓
Hide	$3x$	=	$15 + 21$	You made a mistake. To move +21 from the left side to the right side you need to change the sign of the term.
Hide	$3x$	=	36	You made a mistake. You seem to have made a mistake in moving terms to isolate terms with x on the left side. You made a mistake while adding together the terms +15 and -21 on the right side. Please try again.
Step 2	$3x$	=	$15 - 21$	✓
Step 3	$3x$	=	-6	✓
Hide	x	=	-6	To isolate x you need to divide by 3 on both sides.
Step 4	x	=	-2	✓

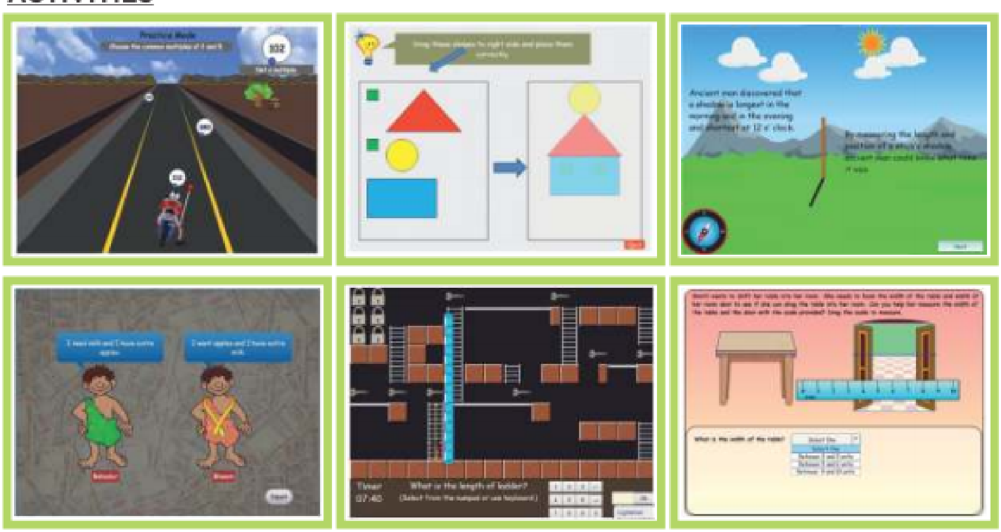
Source: Company documents.

Exhibit 4 Mindspark Student Interface

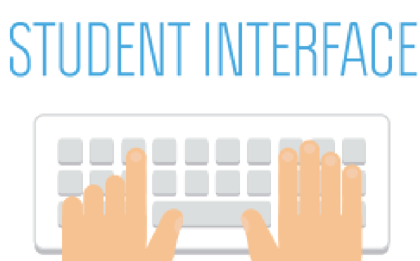
HOME PAGE



ACTIVITIES



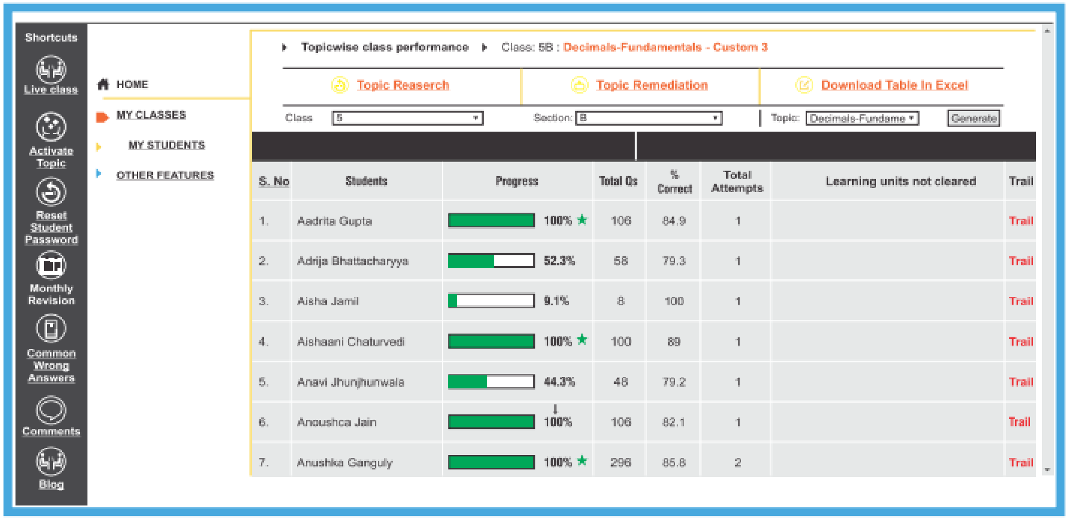
REWARDS CENTRAL



Source: Company documents. Also available at: http://www.ei-india.com/wp-content/uploads/2011/12/Mindspark-brochure-2015.pdf, accessed March 2017.

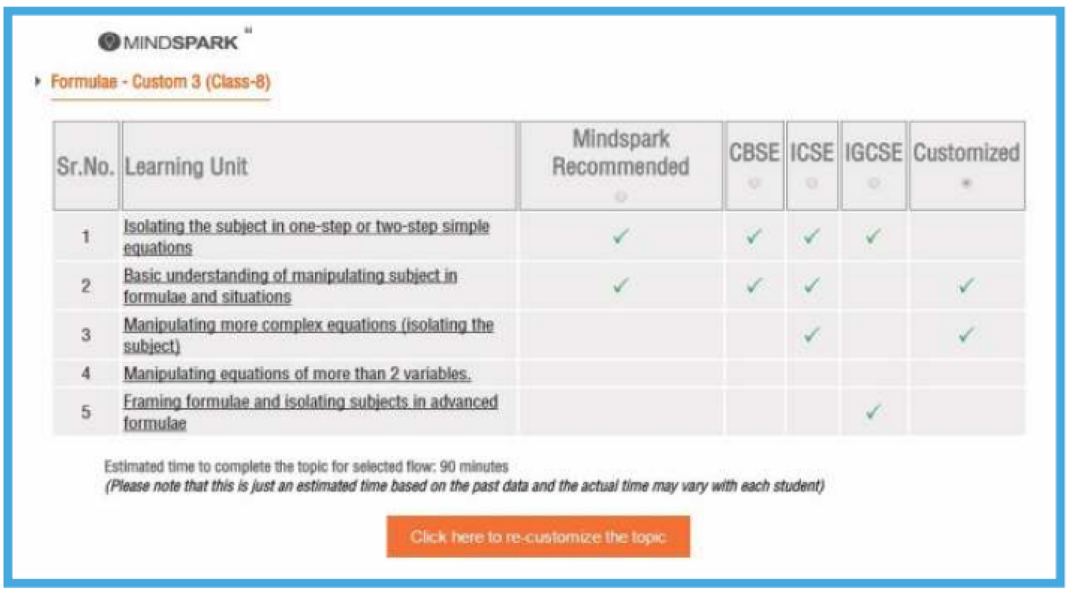
Exhibit 5 Mindspark Teacher Interface

TOPICWISE CLASS PERFORMANCE



S. No	Students	Progress	Total Qs	% Correct	Total Attempts	Learning units not cleared	Trail
1.	Aadrita Gupta	100% ★	106	84.9	1		Trail
2.	Adrija Bhattacharyya	52.3%	58	79.3	1		Trail
3.	Aisha Jamil	9.1%	8	100	1		Trail
4.	Aishaani Chaturvedi	100% ★	100	89	1		Trail
5.	Anavi Jhunjhunwala	44.3%	48	79.2	1		Trail
6.	Anoushca Jain	100%	106	82.1	1		Trail
7.	Anushka Ganguly	100% ★	296	85.8	2		Trail

TOPIC CUSTOMISATION



Sr.No.	Learning Unit	Mindspark Recommended	CBSE	ICSE	IGCSE	Customized
1	Isolating the subject in one-step or two-step simple equations	✓	✓	✓	✓	
2	Basic understanding of manipulating subject in formulae and situations	✓	✓	✓		✓
3	Manipulating more complex equations (isolating the subject)			✓		✓
4	Manipulating equations of more than 2 variables.					
5	Framing formulae and isolating subjects in advanced formulae				✓	

Estimated time to complete the topic for selected flow: 90 minutes
(Please note that this is just an estimated time based on the past data and the actual time may vary with each student)

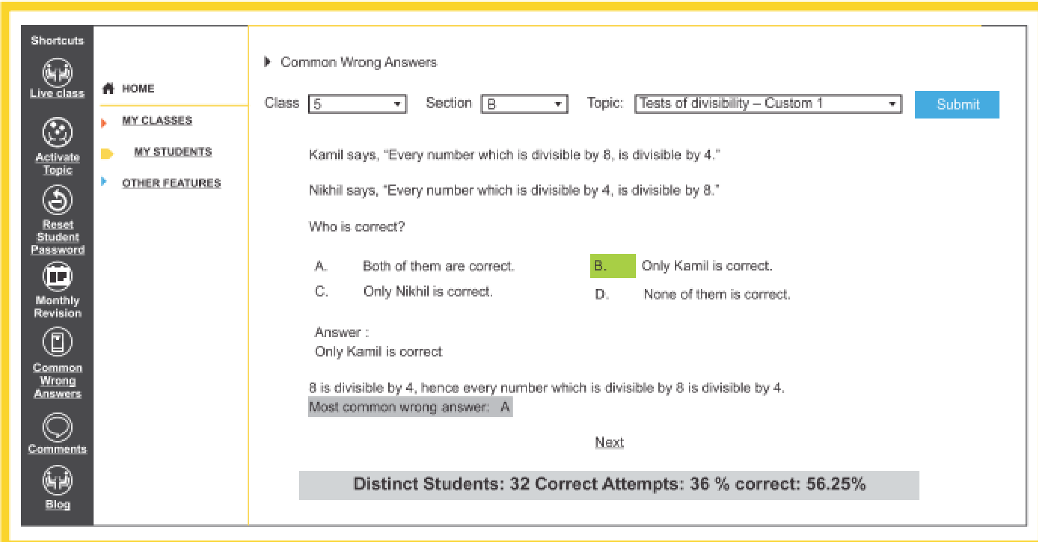
***Teachers can select from the IGCSE, ICSE, CBSE, Mindspark recommended curricula, or customize the topic to suit their teaching flow.**

Source: Company documents. Also available at: http://www.ei-india.com/wp-content/uploads/2011/12/Mindspark-brochure-2015.pdf, accessed March 2017.

Exhibit 6 Mindspark Reports for Teachers

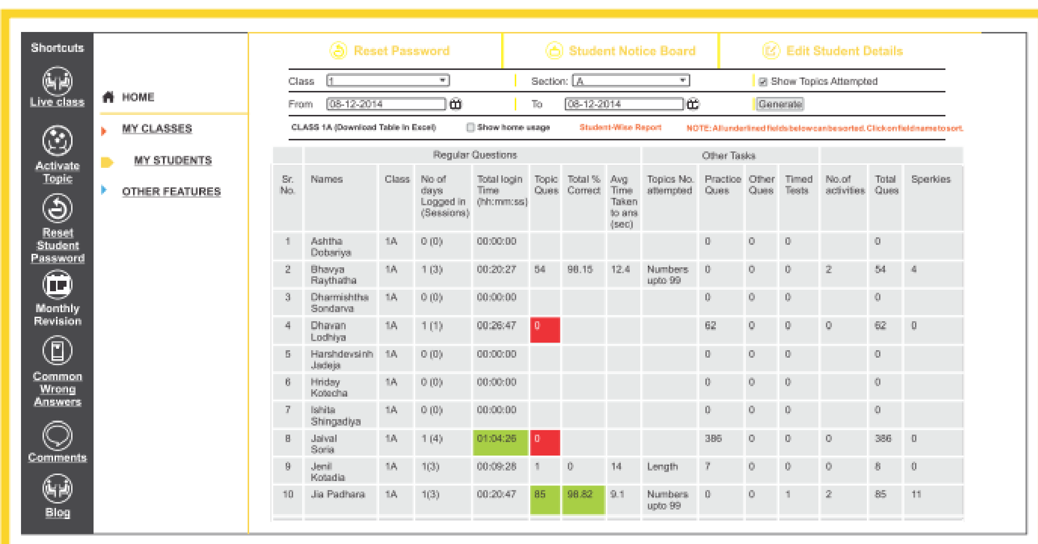
COMMON WRONG ANSWER REPORT

- An extremely beneficial tool that helps diagnose misconceptions at an early stage.
- Teachers can generate the report after every Mindspark session and use the questions to reinforce learning.



CLASS - WISE TOPIC REPORT

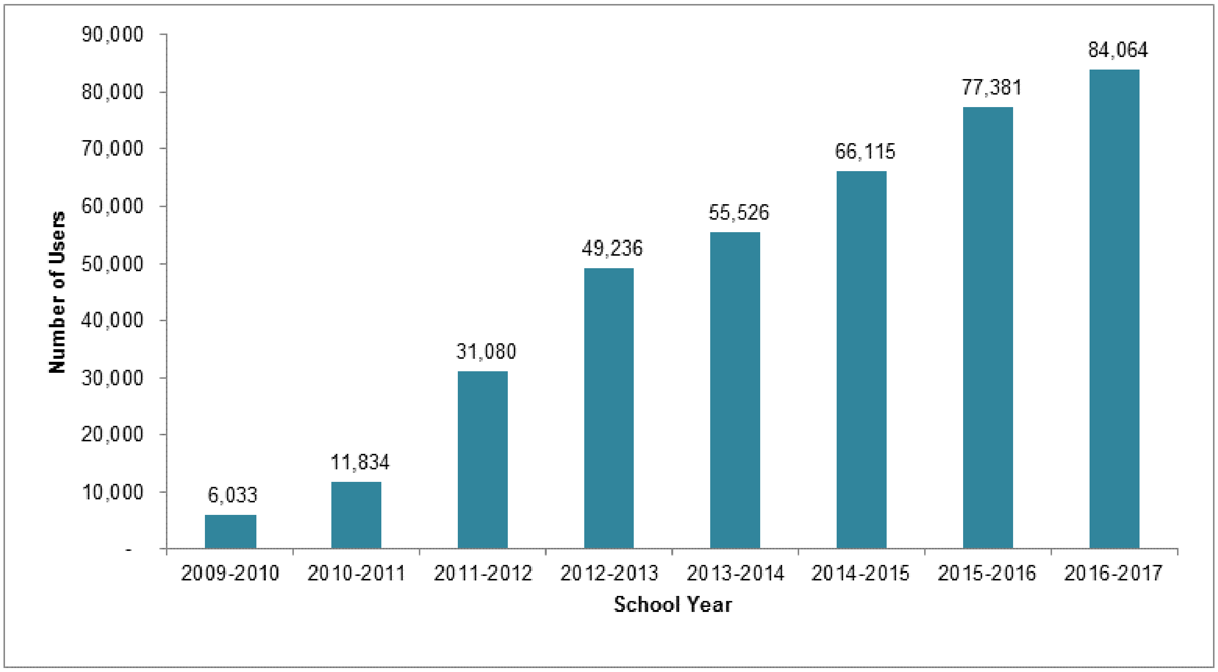
- Provides a snapshot view of class-wise students' performance.
- Teachers can identify specific strong and weak areas of students in the class.



		Regular Questions							Other Tasks						
Sr. No.	Names	Class	No of days Logged in (Sessions)	Total login Time (hh:mm:ss)	Topic Ques	Total % Correct	Avg Time Taken to ans (sec)	Topics No. attempted	Practice Ques	Other Ques	Timed Tests	No.of activities	Total Ques	Sparkies
1	Ashtha Dobariya	1A	0 (0)	00:00:00					0	0	0		0	
2	Bhavya Raythatha	1A	1 (3)	00:20:27	54	98.15	12.4	Numbers upto 99	0	0	0	2	54	4
3	Dharmishtha Sondarva	1A	0 (0)	00:00:00					0	0	0		0	
4	Dhavan Lodhiya	1A	1 (1)	00:26:47	0				62	0	0	0	62	0
5	Harshdevsinh Jadeja	1A	0 (0)	00:00:00					0	0	0		0	
6	Hriday Kotecha	1A	0 (0)	00:00:00					0	0	0		0	
7	Ishita Shingadiya	1A	0 (0)	00:00:00					0	0	0		0	
8	Jaival Soria	1A	1 (4)	01:04:26	0				386	0	0	0	386	0
9	Jenil Kotadia	1A	1(3)	00:09:28	1	0	14	Length	7	0	0	0	8	0
10	Jia Padhara	1A	1(3)	00:20:47	85	98.82	9.1	Numbers upto 99	0	0	1	2	85	11

Source: Company documents. Also available at: http://www.ei-india.com/wp-content/uploads/2011/12/Mindspark-brochure-2015.pdf, accessed March 2017.

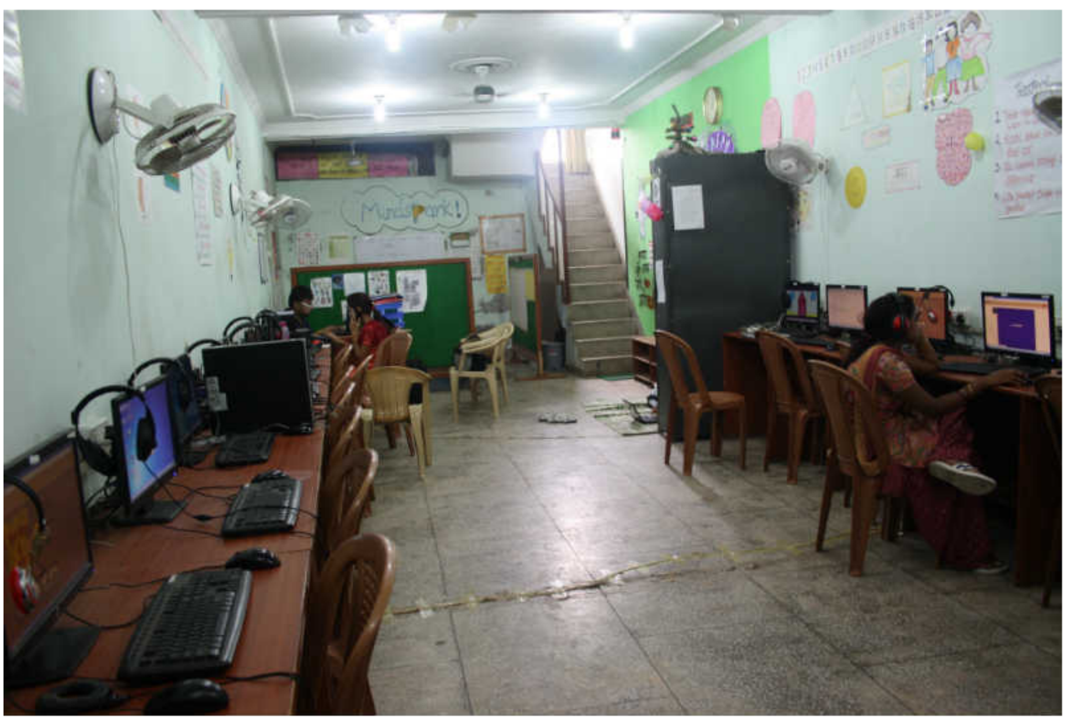
Exhibit 7 Growth in the Number of Mindspark Users in Private Schools



Source: Company documents.

Note: Prior to 2016-2017, only the math product (delivered in English) was available for private schools. In 2016-2017, the English Language Learning product was launched. The 2016-2017 school year had 79,830 users of the mathematics product and 4,234 users of the English product.

Exhibit 8 Mindspark Centers in Delhi



Source: Company documents.

Exhibit 9 The Indian Central Government's Assistance to States for ICT Infrastructure in Each School (Rupees in 100,000)

a.	**Capital Expenditure (Non-recurring)**	
1.	10 PCs (or one Server with 10 Terminals), 1 Projector, 1 Printer, 1 Scanner, 1 Web Camera, 1 modem, Broadband antenna, Generator/ Solar Package, UPS, video camera, etc.	5.10
2.	Operating System & Application Software	0.20
3.	Educational Software and CD ROMs	0.45
4.	Furniture	0.25
5.	*Induction training in ICT to teachers for 10 days @ Rs. 400/- per day (average of 10 teachers).*	*0.40*
	Total	**6.40**
Note: The cost includes Annual Maintenance Contract for a minimum period of 5 years.		
b.	**Recurring**	
1.	Computer Stationery (Printer cartridges, CD-ROMs, DVD, paper, etc.)	0.80
2.	*Electricity charges @ Rs. 1,000/- p.m.*	*0.12*
3.	*Expenses on Diesel /Kerosene for generator @ Rs 1,000/- p.m.*	*0.12*
4.	Telephone charges @ Rs. 500/- p.m.	0.06
5.	Internet / Broadband charges	0.10
6.	*Teachers' salary @ Rs. 10000/- p.m.*	*1.20*
7.	*Refresher training for 5 days to teachers @ Rs. 400/- per day (average of 10 teachers).*	*0.20*
8.	Management, Monitoring and Evaluation	0.10
	Total	**2.70**

Source: "Revised Scheme of Information and Communication Technology in Schools (ICT in Schools) during the XI Plan," Ministry of Human Resource Development, Government of India, http://mhrd.gov.in/sites/upload_files/mhrd/files/upload_document/Revised%20Guidelines%20of%20ICT%20Scheme.pdf, accessed March 2017.

Note: Using March 2017 conversion rates, 640,000 Indian rupees equaled about $10,000 U.S. dollars; and 270,000 Indian rupees equaled about $4,000 U.S. dollars.

Exhibit 10 Schools Approved for ICT Implementation by State

	State / Union Terrority	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17	Total Schools Approved
1	ANDAMAN & NICOBAR												28	**28**
2	ANDHRA PRADESH	200			2852		768				1650		0	**5470**
3	ARUNACHAL PRADESH	114			34	47	17						53	**265**
4	ASSAM			641			1240	969				500	0	**3350**
5	BIHAR	37		832								277	127	**1273**
6	CHANDIGARH		20	67							1	7	2	**97**
7	CHHATTISGARH		100	200	653								1246	**2199**
8	DADRA & NAGAR HAVELI		6	5			4	1					0	**16**
9	DAMAN & DI U	15		8									0	**23**
10	DELHI							1106					68	**1174**
11	GOA			432									56	**488**
12	GUJARAT				3198	1926							174	**5298**
13	HARYANA	100		498		902	1609						87	**3196**
14	HIMACHAL PRADESH				623		615	840		70			0	**2148**
15	JAMMU & KASHMIR										220		407	**627**
16	JHARKHAND										1036		0	**1036**
17	KARNATAKA	480		1568	4396								0	**6444**
18	KERALA	125		847	1455								86	**2513**
19	LAKSHADWEEP		10										0	**10**
20	MADHYA PRADESH	230						2000					0	**2230**
21	MAHARASHTRA			500	2500			4644				1000	500	**9144**
22	MANIPUR			65			264						34	**363**
23	MEGHALAYA				75							100	0	**175**
24	MIZORAM	29				100	41	180					0	**350**
25	NAGALAND	53	147	284			82		121				0	**687**
26	ODISHA							4000	1900				100	**6000**
27	PUDUCHERRY		25					105					0	**130**
28	PUNJAB	199			2000	870	492	5	131				100	**3797**
29	RAJASTHAN	100		2500	2000		2000					525	303	**7428**
30	SIKKIM	103		2			46					17	13	**181**
31	TAMILNADU	125		400	400					4340			0	**5265**
32	TELANGANA				2148		532				2175		0	**4855**
33	TRIPURA			400			179						0	**579**
34	UTTAR PRADESH			2500			1500	1608					0	**5608**
35	UTTRAKHAND	25		100			500						0	**625**
36	WEST BENGAL			540	1385		1990						1091	**5006**
	Total	**1935**	**308**	**12389**	**23719**	**3845**	**11879**	**15458**	**2152**	**4410**	**5082**	**2426**	**4475**	**88078**

Source: "Physical and Financial Status," Information and Community Technology (ICT), Ministry of Human Resource Development, Government of India, http://mhrd.gov.in/ict_physical_targets, accessed March 2017.

Exhibit 11 Status of ICT Implementation of Approved Schools by State

	States / Union Territories	Number of Schools Approved for ICT	Number of Schools with ICT Implemented	Percentage of Approved Schools with ICT Implemented	Number of Approved Schools without ICT Implemented	Number of Schools that Completed 5 Years of Implementation
1	Andaman & Nicobar Island	28	-	-	28	-
2	Andhra Pradesh	5,470	3,820	70	1,650	3,820
3	Arunachal Pradesh	265	195	74	70	195
4	Assam	3,350	2,850	85	500	641
5	Bihar	1,273	869	68	404	869
6	Chandigarh	97	95	98	2	72
7	Chhattisgarh	2,199	953	43	1,246	300
8	Dadra & Nagar Haveli	16	16	100	-	11
9	Daman & Diu	23	23	100	-	23
10	Delhi	1,174	1,106	94	68	-
11	Goa	488	432	89	56	432
12	Gujarat	5,298	5,124	97	174	5,124
13	Haryana	3,196	3,109	97	87	1,500
14	Himachal Pradesh	2,148	2,137	100	11	623
15	Jammu & Kashmir	627	220	35	407	-
16	Jharkhand	1,036	-	-	1,036	-
17	Karnataka	6,444	3,048	47	3,396	2,048
18	Kerala	2,513	2,427	97	86	2,427
19	Lakshadweep	10	-	-	10	-
20	Madhya Pradesh	2,230	230	10	2,000	230
21	Maharashtra	9,144	7,644	84	1,500	3,000
22	Manipur	363	329	91	34	325
23	Meghalaya	175	75	43	100	75
24	Mizoram	350	290	83	60	167
25	Nagaland	687	687	100	-	687
26	Odisha	6,000	4,000	67	2,000	-
27	Puducherry	130	130	100	-	25
28	Punjab	3,797	3,566	94	231	3,566
29	Rajasthan	7,428	7,125	96	303	4,600
30	Sikkim	181	168	93	13	105
31	Tamil Nadu	5,265	925	18	4,340	925
32	Telangana	4,855	2,680	55	2,175	2,680
33	Tripura	579	400	69	179	400
34	Uttar Pradesh	5,608	4,000	71	1,608	4,000
35	Uttrakhand	625	125	20	500	125
36	West Bengal	5,006	3,914	78	1,092	1,925
	Total	**88,078**	**62,712**	**71**	**25,366**	**40,920**

Source: Company documents.

Endnotes

[1] Muralidharan, Karthik, Abhijeet Singh, and Alejandro J. Ganimian. Disrupting Education? Experimental Evidence on Technology-Aided Instruction in India. No. w22923. National Bureau of Economic Research, 2016.

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